MACDONALD COLLEGE
(McGILL UNIVERSITY)
Technical Bulletin No. 15

AGRICULTURAL COLLEGE, COIMBATORE.
1936
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THE VALUE OF PRELIMINARY UNIFORMITY TRIALS IN INCREASING THE PRECISION OF FIELD EXPERIMENTS

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OCTOBER, 1934

Technical Bulletin No. 15 October, 1934

The Value of Preliminary Uniformity Trials in Increasing the Precision of Field Experiments

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THE VALUE OF PRELIMINARY UNIFORMITY TRIALS IN INCREASING THE PRECISION OF FIELD EXPERIMENTS

By

R. SUMMERBY

ABSTRACT:— With a view to determining the value of preliminary uniformity trials for increasing the precision of field experiments, each of four ranges of land approximately three-quarters of an acre in area was divided into plots 20 by 20 links and cropped uniformly each year for ten to twelve consecutive years. Assuming five different plotting plans involving two sizes of plots, an analysis of variance was calculated for each range each year. The relative precision of the error variances was determined for single plots and as well for a sufficient number of replications to take up the same area of land.

With the same plotting plans an analysis of co-variance of assumed preliminary tests and subsequent trials on corresponding plots was made for consecutive yearly yields, for yearly yields several years apart, and for the average of a period of years and subsequent yearly yields. Regression and correlation coefficients for the remainder or error were determined.

Using the regression of the trial yields on the preliminary yields as a basis of adjustment, the residual or error variances adjusted for the preliminary yields were calculated. The relative precision attained by this adjustment was determined by dividing each error variance obtained thereby into the corresponding error variance before adjustment.

Out of 134 correlation coefficients calculated, 77 reach the level of significance as measured by $P = .05$. Of these three are negative. When the yearly yields of trial years are adjusted for the regression on their preliminary yields there is often an improvement in precision; it is seldom great however, and the conclusion is drawn that the use of preliminary uniformity trials for the purpose of adjusting yields of subsequent experiments by regression is only rarely as effective in increasing the precision of an experiment as is the use of the same amount of land and labour in the year of the trial.

A. INTRODUCTION

It is now very generally recognized in field experimental work that soil variation is responsible for large differences in yield and other crop characters, entirely apart from any experimental treatment that may have been applied. It is therefore necessary to associate with any measurement of the effect of treatment such as yield, a measure of the variability that

may normally be expected under the conditions of the experiment. The constants which are in use for this purpose include the standard deviation or standard error, the coefficient of variation, the probable error, and the variance. These are all closely related and may be used to determine: the difference that may be expected by even chance, the probability of any difference obtained in an experiment occurring by chance, or the size of the difference that is required to give any desired degree of certainty.

The results of many experiments make it abundantly clear that the variability applicable to field experiments differs greatly in different fields, in different years, and with different crops. This is due to the differences occurring in soil, in weather conditions, in crop requirements, and the interaction of these. In practice, differences of ten per cent between single plots of large size are not abnormal, while differences of thirty and forty per cent are sometimes obtained between single small plots.

With a view to making field experiments as efficient and economical as possible, a great deal of experimental work has been done on those factors which have a bearing on the extent of variation, as, for example, the size of plots, frequency of replication, the use of check plots for adjusting yields, etc. It is now accepted that by local control, and replication, one can increase the accuracy of an experiment to any desired point and that a valid estimate of error requires replication and randomization. If an experiment is planned in accordance with these principles the contributions of the treatments being studied can be separated out by an analysis of variance, and it can be determined which ones are significant.

In spite of the very great improvement made in methods of experimentation, field experiments still leave much to be desired from the standpoint of cost. Information as to methods that will improve on the precision without additional cost or give equal precision at lower cost is of very great value.

The use of preliminary uniformity trials in which the land devoted to an experiment is seeded to a uniform crop and harvested by plots so as to obtain the relative productivity of different parts of the field, has frequently been suggested by experimenters as a basis for increasing the efficiency of field experiments. When an experiment is to involve a series of crops in rotation, some experimenters have urged that, in order to get preliminary information on the land to be devoted to the experiment, a full course of the rotation should be run, a uniform crop without special treatments being grown each year.

Such uniformity trials may be useful in several different ways. They may be used to determine the size, shape, and arrangement of plots best suited to the field; they may be used to eliminate unsuitable areas; they may be used as a basis for dividing the field into blocks, so that each of the replications of a proposed experiment may be located on relatively uniform land, thereby getting the greatest local control; or they may be used

for adjusting yields by making allowance for high and low yielding areas of land by one means or another.

B. PREVIOUS WORK

In 1915 Harris called attention to the possible usefulness of inter-annual correlations in increasing the efficiency of experiments with animals, plants, or soils.

Harris and Schofield (1920, 1928) studied the permanence of differences in the plots of an experimental field comprising 46 plots and involving six crops, at Huntley Field Station, Montana, over a period of fifteen years. By applying the method of inter-annual correlation, the authors demonstrated that plots which showed a high yield in one year were generally characterized by measurably higher yields in subsequent years. Out of 874 correlations calculated, 108 were essentially in the zero class (0.05 to —0.05); apart from these, 498 were positive and 268 were negative. In addition to there being a larger number of positive than of negative correlations, the former on the whole had distinctly higher values.

Sanders (1930) studied data from two experimental fields in Denmark. He corrected the variance for error of the experimental yields by means of the regression function between the preliminary yields and the experimental yields. In one field he found that there was an increase in precision of nearly 150 per cent, while in the other field there was no increase at all.

Garber and Hoover (1930), at Lakin, West Virginia, studied the persistence of soil differences with respect to soil productivity on 270 one-fiftieth acre plots. Uniform crops of oats and wheat were grown in 1923 and 1924 respectively; and in the five following years cropping plan experiments were conducted. Correlation studies were made between the deviations of duplicate plots in the uniformity trials and those of duplicate plots in subsequent years. The correlation coefficients were all found to be positive, and all but one were significant. Natural differences in the productivity of the plots persisted over a period of five years, even though the plots were subjected to different treatments.

Garber, McIlvaine, and Hoover (1931) studied another field at Lakin, West Virginia. Uniformity crops of corn, oats, and wheat were grown in consecutive years. The yields of grain, straw and stover were expressed as percentage deviations from their means, and the correlations between the relative yields were obtained. The correlations in this case were all positive and significant, ranging from 0.20 to 0.70 with probable errors of $\pm$ 0.03 to $\pm$ 0.02 respectively. On the basis of their study, the authors suggest possible uses of uniformity trials as follows: (a) those plots which show extreme deviations may be eliminated, and (b) the average deviations of the remainder may be used for selecting replicates.

T. Eden (1931) working with tea yields, divided 42 pluckings into 3 groups of 14. He used the yields of the first group, the yields of the

second group, and the yields of the average of the two to adjust the subsequent or supposed experimental yields represented by the third or last group. Applying the method suggested by Sanders (1930), he obtained relative precisions of 5.87, 1.65, and 5.46 respectively for these three different bases of adjustment.

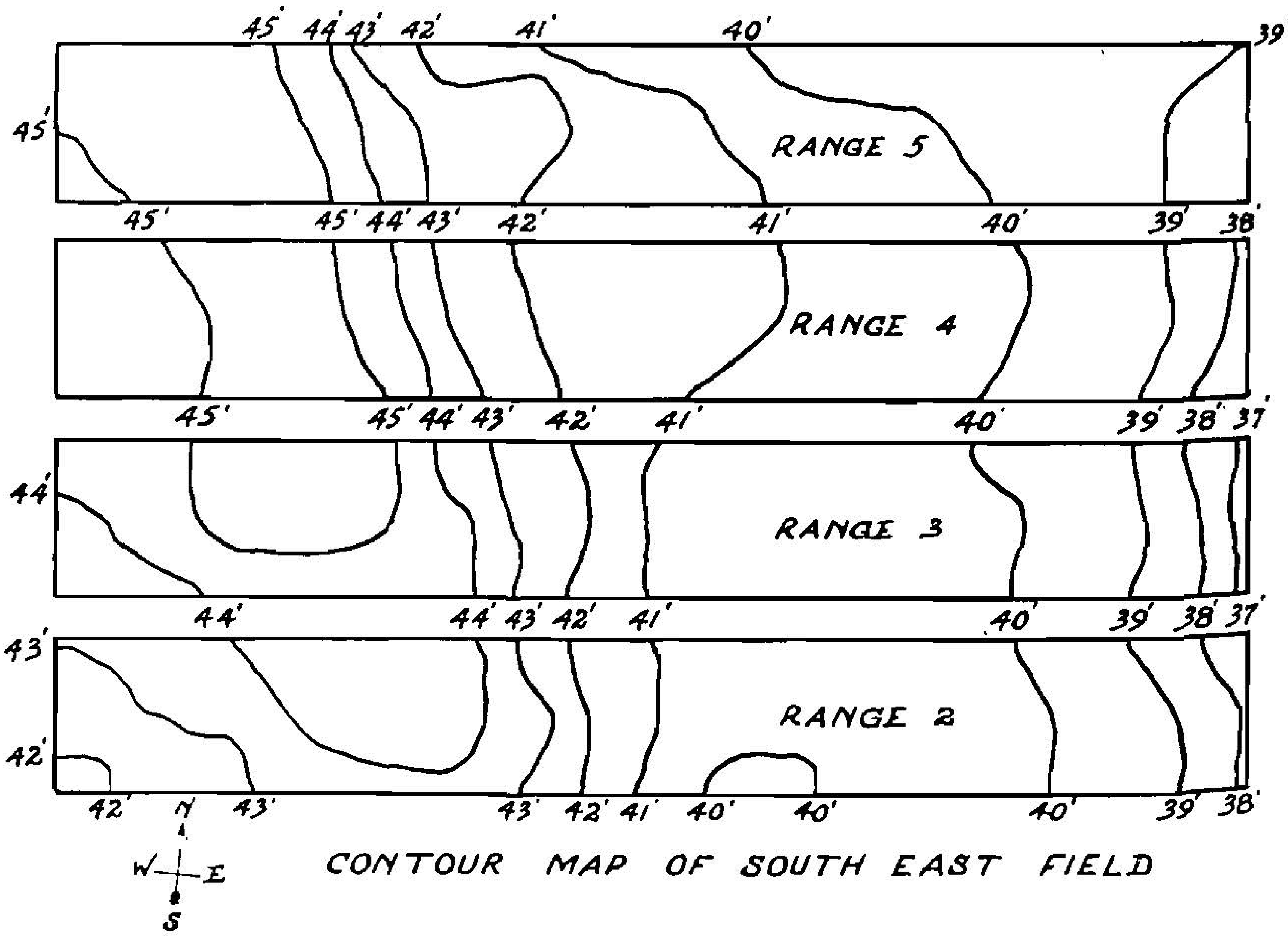
Murray (1934) studied the value of a uniformity trial in field experimentation with rubber using the methods of Fisher and Sanders. Taking the 1926 data for adjusting those of 1927, 1928, and 1929 he obtained relative precisions of 3.74, 2.52, and 2.15 respectively.

C. MATERIAL AND METHODS

Starting in 1922, about four acres of land in what is known as the Agronomy South East Field, Macdonald College, Que., were set apart for a time for the purpose of studying field plot technique and to provide, if possible, a basis for future experiments on this area. The soil of this area is of a gravelly loam nature, is moderate in fertility, and well drained. There are easily observable differences in the texture of soil and subsoil, the depth of surface soil, in the contours of the land, and other qualities indicative of productivity, but as compared with other land in the vicinity it would be called reasonably uniform.

MAP SHOWING CONTOURS OF AREA STUDIED

Figures indicate feet above bench mark.



The field had been divided about ten years previously into ranges for variety and strain tests. Other than for differences between varieties, each range had had uniform treatment for at least fifteen years previous to the start of this work. In all, four ranges of land, each 0.76 acre in size (760 links × 100 links), have been in use for this study.

Table 1 gives the kind of crop grown on each of the four ranges during the period for which data were obtained and studied:

TABLE I. CROPS GROWN ON DIFFERENT RANGES.

Year	Range 2	Range 3	Range 4	Range 5
1922	Maize	Oats		
1923	Maize	Oats		
1924	Maize	Oats	Alfalfa	Oats
1925	Maize	Oats	Alfalfa	Oats
1926	Maize	Oats	Mangels	Oats
1927	Oats	Maize	Oats	Mangels
1928	Clover	Oats	Maize	Oats
1929	Timothy	Clover	Oats	Maize
1930	Maize	Timothy	Clover	Oats
1931	Oats	Maize	Timothy	Clover
1932	Clover	Oats	Maize	Timothy

It will be noted that in the earlier years of this experiment corn was grown continuously for five years, oats for five years, alfalfa for two years, and oats for three years on ranges 2, 3, 4, and 5 respectively. In latter years the land has been in a rotation in which the crops occurred in the order maize, oats, clover, and timothy. The four most important farm crops in this section of the country are thus represented.

North Western Dent, Grimm, and Yellow Intermediate respectively were the varieties of maize, alfalfa, and mangels used throughout the experiment. Banner 44 oats were grown on range 5 in 1924, 1925, and 1926, and on ranges 2 and 4 in 1927. The Cartier variety was grown on range 2, 1932, and in all other cases where oats were grown the Alaska variety was used. The clover and timothy were seeded with the preceding oat crop at the rate of 9 pounds of red clover, 2 pounds of alsike, and 5 pounds of timothy. Mangels were shown in rows 4 links apart and were thinned to single plants one link apart in the row. The corn was sown in hills 5 links × 5 links apart, with 5 seeds per hill, and the plants were thinned to three per hill. Oats were sown in drills at 2 to 2.5 bushels per acre. Throughout the experiment good cultural treatments were given.

Up to the start of this experiment, manure had been applied regularly to keep the land in a fair state of fertility. From the time when data were first taken on any range,no manure was applied until after the 1926 crop had been removed, when 20 tons per acre were applied to each of the four ranges. Thereafter, manure was applied following the timothy and pre-

ceding the maize crop. Range 2 had an application of 16 tons after the 1929 crop; range 3 had an application of 16 tons after the 1930 crop; range 4 had an application of 10 tons after the 1927 crop, and 16 tons after the 1931 crop; and range 5 had an application of 16 tons after the 1928 crop.

The applications in all cases were of well-rotted stockyard manure, which was thoroughly mixed by repiling it along different planes several times just before applying it. The exact amount of manure to make the tonnages specified above was weighed out for each plot separately and spread evenly over it.

From 1922 to 1926 inclusive, all crops involved in this study were harvested in such a way as to make up plots 20 by 20 links. Range 5 was harvested in this way in 1927 also. In the succeeding years all crops were harvested in plots 20 by 100 links. Data were thus available for studying plots 20 by 20 links up to 1926 for all ranges, excepting range 5, for which similar data were obtained for an additional year. By grouping yields of five plots running across a range together in the earlier years, data were made available for studying plots 20 by 100 links throughout the full period on all ranges.

In the case of oats, clover, and timothy, the plots were indicated by cutting out a three inch strip between the plots after the crops were well up. This could have no important effect upon yield and left the plots essentially contiguous. In mangels and in maize, the plants were so spaced as to have the dividing line between plots fall half way between two rows in one direction and half way between plants in the row in the other direction.

In oats the data upon which the present study is based were the yields of cleaned grain. In mangels, clover, timothy, and alfalfa, the yields of dry matter were calculated from the total plot yields and the percentage dry matter determinations made from samples taken therefrom. In maize the green weights of fodder were taken from 1922 to 1926. Thereafter the dry matter weight of ears was obtained in the same way as was done for mangels, etc.

Three crops of alfalfa were harvested in 1924, and two were harvested in 1925. Two cuts of clover were taken in all years where this crop was grown, except in 1932, when only one was harvested. The total annual yields alone are used in this study.

In 1925 the yields of Alaska oats on range 3 were considered valueless on account of bird injury. In 1927 the crop of oats on range 4 was badly lodged and tangled so that it could not well be harvested. In 1931 on range 4 the stand of timothy was very poor, and weeds were quite prevalent in it. For these reasons the data thereon were not available for study.

In 1924 there was some flooding on range 5 by water from a coal pile on an area nearby, and it was considered inadvisable to include this area in this study. This eliminated 11 of the larger-sized plots from the study of this range.

The yields of the plots of Alaska oats on range 3 in 1924 were extremely variable, probably due to a poor stand in some parts resulting from wet, cold weather which prevailed in that year at and after seeding time. There are reasons why this year's data should be excluded from the study because of this abnormality, but for the sake of completeness they have been included.

Records of temperatures and precipitation were taken in the Department of Horticulture, the instruments being located about two hundred yards from the area under study. The records of these temperatures and also the yields are to be found in the appendix.

D. METHOD OF USING PRELIMINARY UNIFORMITY TRIALS IN INCREASING THE PRECISION OF SUBSEQUENT EXPERIMENTS

In attempting to measure the influence of varieties or treatments, the values obtained in any experiment must have associated with them a measure of the variation obtaining under the conditions of the trial. As variance is the basis from which all of the standard measures of variation or error are determined, it will be used as the measure of variability in this paper. Since the significance of any value is determined by the variance that is associated with it, any method of using uniformity trials that reduces the variance will increase the precision, and vice versa.

If one does not have previous uniformity trials, the variance to be associated with any measurement of the effect of treatment must be obtained from the data of the experiment itself. If, however, preliminary information is available as to the yielding ability of the land, and it is found therefrom that certain parts or plots of a field are better than others, then it should be possible to correct for this by appropriate methods.

One of the simplest ways of doing this is to express both the preliminary uniformity yields and the experimental yields of plots as percentages of their respective means. Then if, on substracting the yield of one plot from its corresponding yield in another period, the experimental yield is found to be the greater, this indicates that the treatment involved has been beneficial in relation to the other treatments in the experiment to the extent of the difference, and vice-versa. As Sanders (1930) points out, however, statistically this method may lead to a loss in precision for, following the formula for obtaining the variance of a difference

$$V_{(x-y)} = V_y + V_x - 2r_{xy}\sqrt{V_xV_y}$$

if there is no correlation between the preliminary and the experimental yields, the two variances would be added together to obtain the variance of the difference which measures the effect of the treatment. Or if there is a correlation and the two variances turn out to be equal or nearly so, no reduction in the variance is possible unless the correlation is at least 0.50. Again, if the correlation is found to be negative, the variance would be greatly increased. This, therefore, cannot be considered as a dependable

or efficient method of using prliminary information for correction, for differences in soil productivity.

A more reliable and efficient method is one proposed by Sanders (1930), in which use is made of the regression function between the two variables or, in this case, between the preliminary yields and the subsequent yields. If the plots in parts of a field which give high yields in the former give on the average either high or low yields in the latter, it is possible to calculate the regression, which shows the average deviation from the mean yield to be expected in the subsequent yield on the basis of a deviation of one unit in the preliminary year. From this regression it is possible to determine the reduction or addition that should be made to the yield of a plot due to the land being better or worse than the average. The subsequent yields can therefore be adjusted for the preliminary yields, and so have the effect of conducting the experiment on land of equal levels of fertility as judged by preliminary yields except for normal variation.

The formula used by Sanders for obtaining the variance applicable to an experiment handled in this way is here given

$$V_{y.x} = V_y - \frac{(Cov_{xy})^2}{V_x}$$

where x stands for preliminary yields, y for subsequent yields, Cov for covariance and $V_{y.x}$ for variance of y corrected for x.

Working on the same principles as Sanders, Fisher (1932), in discussing covariance, shows how it may be employed to make use of preliminary information to increase the precision of subsequent experiments. Using as an example tea yields (data of T. Eden) taken from the second and third crop as preliminary and experimental data respectively, he shows a simple method of obtaining the covariance, and how the total covariance may be analysed into portions attributable to blocks, rows, columns, etc., in a manner exactly analogous to that already familiar in the analysis of variance. Furthermore, he gives formulae and illustrates how an analysis of variance of yields corrected for the preliminary yields may be obtained.

The general formula followed is

$$S(y - bx)^2 = S(y^2) - 2\,b\,S(xy) + b^2\,S(x^2)$$

where b is the regression coefficient calculated from the residual variance and covariance, after the elimination of block, treatment, and other differences, $S(x^2)$ is the sum of squares of the deviations of the preliminary yields from their mean yield, $S(y^2)$ is the sum of squares of the deviations of the subsequent or experimental yields from their mean yields, and $S(xy)$ is the sum of the products of the deviations of the preliminary and subsequent yields from their respective means. The corrected variance for each of the portions is found by dividing their sums of squares by the appropriate number of degrees of freedom.

The methods given by Fisher have been followed in calculating the error variances of subsequent or supposed experimental yields, and also the

corresponding variances adjusted on account of the data obtained in the preliminary trials, for several assumed plans of plotting as follows:—

Plots 20 × 20 Links

(a) treatments distributed at random throughout the whole area of each range, 700 × 100 links, (500 × 100 on range 5);

(b) treatments distributed at random within blocks 100 × 100 links;

(c) treatments located at random within 5 × 5 latin squares 100 × 100 links, with the restrictions that any treatment may not occur more than once in each row or column of the square;

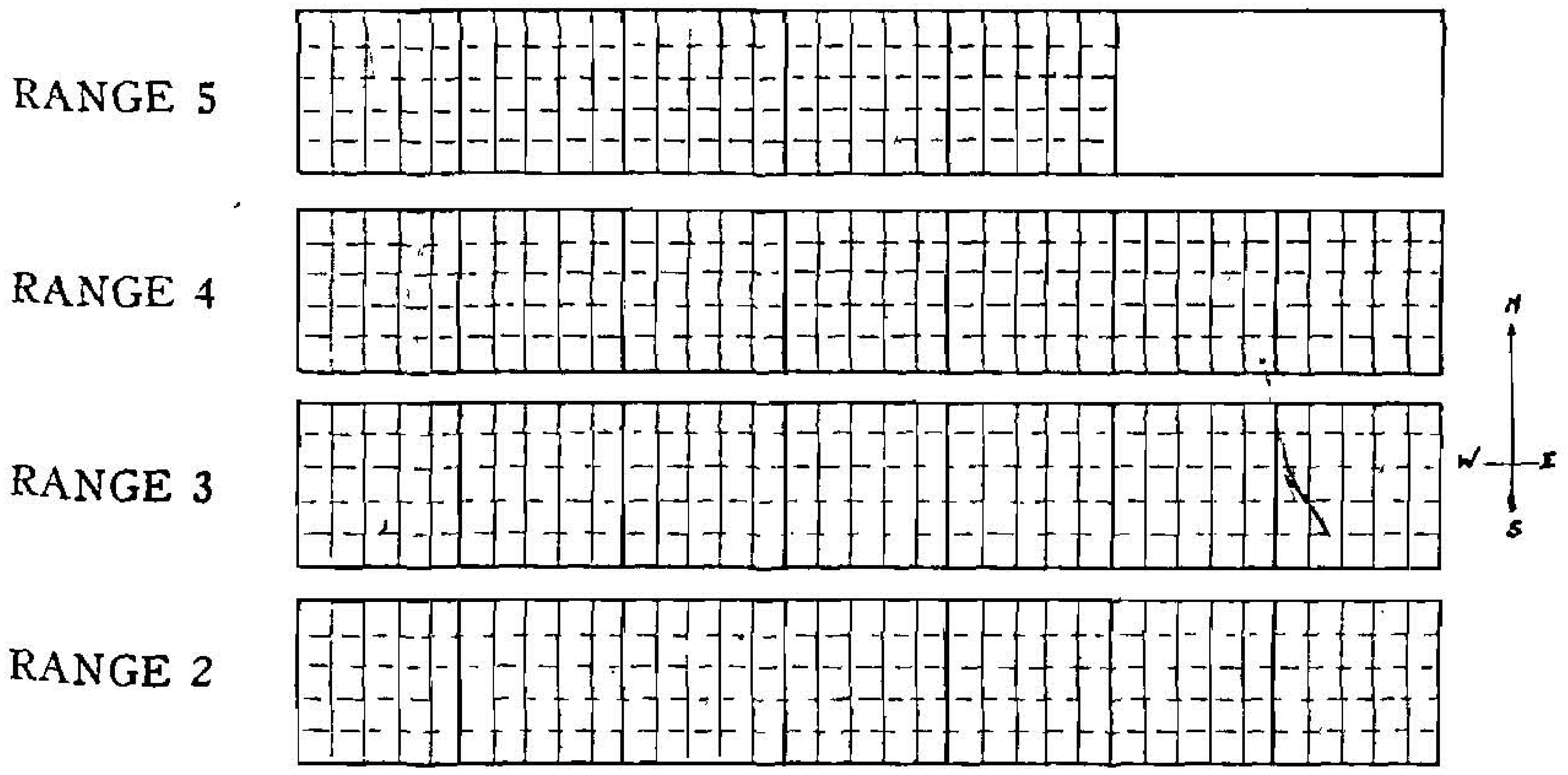
Plots 20 × 100 Links

(d) treatments distributed at random throughout the whole range, 700 × 100 links (500 × 100 on range 5);

(e) treatments distributed at random within blocks 100 × 100 links;

A plan of the field showing the ranges, plots, and methods of plotting studied is here given.

PLAN OF AREA STUDIED SHOWING ARRANGEMENT OF PLOTS.



In order to have the procedure clear, it will be best to follow through an example using data from one range for two years, the first representing the preliminary test and the second the subsequent or experimental trial. The following illustrations have been taken from range 2 in the years 1922 and 1923 (see appendix).

(a) Plots 20 X 20 links. Treatments distributed at random over the whole range.

Sum of Squares 1922 $S(x^2)$	1923 $S(y^2)$	Sum of Cross Products $S(xy)$	Regression Coefficient (b) $\frac{S(xy)}{S(x^2)}$	Sum of Squares of 1923 Yields Adjusted for 1922 $S(y - bx)^2$
Error 14,338,307.	44,331,786	6,676,249	0.4656	41,223,169

If we had no preliminary information, that is if 1923 stood by itself, the variance would be based upon the sum of squares for that year, namely, 44,331,786. However, we have the 1922 yields, and we find that the regression of the yield of an individual plot in 1923 on the yield of the same plot in 1922 is 0.4656. This indicates that a plot which yields one unit above the mean of the whole range in 1922 can be expected on the average to yield 0.4656 units above the mean in 1923. We can therefore calculate how much each yield of 1923 is higher or lower than it would have been if the values of 1922 had all been equal. In other words, we calculate the values for 1923 with the 1922 yields held constant. The variance of the corrected 1923 yields can be obtained by correcting each individual yield and then calculating the variance, or it can be obtained by the formula $S(y^2) - 2\,b\,S(xy) + b^2\,S(x^2)$. Since the value of the terms in this formula have all been obtained above, it is only necessary to substitute in the above equation as follows:—

$44{,}331{,}786. - 2 \times 0.4656 \times 6{,}676{,}249 + 0.21678 \times 14{,}338{,}307. = 41{,}223{,}169.$

This is the corrected error sums of squares applicable to this experiment, and to obtain the variance it is simply necessary to divide by the proper number of degrees of freedom. The correct number of degrees of freedom for the unadjusted 1923 yields is 174, but owing to the calculation of one additional constant (b) we have to allow one degree of freedom therefor, and so in this case the number of degrees of freedom for adjusted yields is 173. The error variance of unadjusted yields is, therefore, 254,780, while that of the adjusted yields is 238,284. These variances are those applicable to single plots placed at random in the whole range.

It is worthy of note that if the corrected sum of squares is to be obtained accurately by the algebraic method, the value of (b) used must be calculated quite accurately. In the above problem seven places of decimals must be carried.

(b) *Plots* 20 × 20 *links. Treatments distributed at random within blocks* 100 × 100 *links*

In this case the plan is designed to make the comparisons within blocks, and so obtain more local control. Since the land is divided up into blocks, it is possible to divide the total sums of squares and cross products obtained in (a) above into two parts, i.e., that due to block differences, and a remainder from which is obtained the error applicable to this design. The procedure from this point on is similar to that followed in (a) above. This works out as follows,—

	Sums of Squares 1922 $S(x^2)$	Sums of Squares 1923 $S(y^2)$	Sums of Cross Products 1922-23 $S(xy)$	Regression Coefficient (b) $\frac{S(xy)}{S(x^2)}$	Sum of Squares of 1923 Yields Adjusted for 1922 $S(y-bx)^2$
Blocks	3,976,806.	18,273,320.	3,196,701.		
Remainder (error)	10,361,501.	26,058,466.	3,479,547.	0.3358	24,889,981.

The error sum of squares applicable to an experiment carried on under these conditions in which the land is divided up in this way, and in which the comparisons are made within blocks, has been reduced by adjustment from 26,058,466 to 24,889,981. Dividing these by the appropriate degrees of freedom 168 and 167 respectively, the error variance is lowered from 155,109 to 149,041.

(c) *Plots* 20 × 20 *links. Treatments located at random within* 5 × 5 *latin squares,* 100 × 100 *links*

This design provides for additional local control, and one can eliminate from the error of (b) above the effect of rows and columns, leaving the part that is applicable to error for this design.

The results are here given.

	Sums of Squares 1922 $S(x^2)$	Sums of Squares 1923 $S(y^2)$	Sums of Cross Products $S(xy)$	Regression Coefficient (b) $\frac{S(xy)}{S(x^2)}$	Sum of Squares of 1923 Yields Adjusted for 1922 $S(y-bx)^2$
Rows	4,297,737.	7,761,809.	3,404,361.		
Columns	2,442,784.	12,979,014.	-604,861		
Remainder (error)	3,620,980.	5,317,641.	680,048.	0.1878	5,189,923.

In this case the sum of squares for error has been reduced by adjustment from 5,317,641 to 5,189,923, and by dividing these by the appropriate degrees of freedom, namely, 112 and 111 respectively the variance is lowered from 47,478 to 46,756.

(d) *Plots* 20 X 100 *links. Treatments distributed at random throughout the range*

This design corresponds to that of (a) except that the same area is divided into larger and fewer plots. The calculations are as follows:—

	Sums of Squares		Sum of Cross Products	Regression Coefficient (b)	Sum of Squares of 1923 Yields Adjusted for 1922
	1922	1923			
	$S(x^2)$	$S(y^2)$	$S(xy)$	$\frac{S(xy)}{S(x^2)}$	$S(y-bx)^2$
Error	41,372,717.	130,175,649.	33,005,368.	0.7977	103,845,391.

By dividing the unadjusted and the adjusted sums of squares by their proper degrees of freedom 34 and 33 respectively the variance is found to be reduced from 3,828,695 to 3,146,830.

(e) *Plots* 20 X 100 *links. Treatments distributed at random within blocks* 100 X 100 *links*

This corresponds to method (b) in that the whole of each range is divided into blocks 100 X 100 links. The data for error in (d) above may be divided up as follows:—

	Sums of Squares		Sums of Cross Products	Regression Coefficient (b)	Sum of Squares of 1923 Yields Adjusted for 1922
	1922	1923			
	$S(x^2)$	$S(y^2)$	(xy)	$\frac{S(xy)}{S(x^2)}$	$S(y-bx)^2$
Blocks	19,884,031.	91,366,600.	15,983,508.		
Remainder (error)	21,488,686.	38,809,048.	17,021,859,	0.7921	25,325,502.

In this design by dividing the unadjusted and the adjusted sums of squares by 28 and 27 respectively the variance is found to be reduced from 1,386,037 to 937,981.

Since in both the preliminary and the supposed subsequent trials each entire range received uniform seed, treatments, etc., the effects of different treatments are not involved. The contributions of blocks, rows, and columns represent the amount of variance or variation that is eliminated by arranging the tests as specified. The remainder is what is attributable to error and is the part in which we are interested. The smaller the variance for error the more accurate is the method and the smaller the difference that can be measured.

E. DISCUSSION OF RESULTS

Before proceeding to discuss the value of preliminary uniformity trials in adjusting yields of subsequent experimental trials by means of regression, it is important to know the error variance occurring before adjustment is made, and to what extent this is reduced by the several plotting plans.

When calculated in the usual way, the variances for plots 20 × 100 links because of their larger size are not comparable with those for plots 20 × 20 links. To make them directly comparable it is necessary to divide the former by 25, since the plots are five times as large and we are dealing with squares. The unadjusted variances for error reduced to a common unit basis in this way are given in Table 2. for five different plotting plans involving two different sizes of plots. These error variances are for single plots and do not take into account the fact, that plots 20 × 20 links require only one-fifth the area of that needed for plots 20 × 100 links and so allow for five-fold replication on the same area of land.

1. VARIATION ON DIFFERENT RANGES, IN DIFFERENT YEARS, AND WITH DIFFERENT CROPS

An examination of these results shows that on the same range and with the same crop there is a very great difference in the error variances obtained in different years, whichever method of plotting is used. For example, on range 3 in 1926 the error variance of yields of oat plots 20 × 20 links distributed wholly at random (472,088) is over three times as large as it is in 1923 (154,784). Similarly, on range 5 in 1925 the variance for oat plots 20 × 100 links distributed wholly at random (200,652) is over six times as great as it is in 1926 (30,715).

Again, the variances for the same crop on different ranges and in the same year are quite different. In 1924 the error variance of the yields of oat plots 20 × 20 links, distributed wholly at random on range 3 (252,451) is nearly twice as great as it is on range 5 (134,472). Similarly, with the same plotting plan in 1926 on range 3 the variance for oat yields (472,088) is over three times as great on range 3 as it is on range 5 (131,714).

TABLE 2. ERROR VARIANCE OF SINGLE PLOTS FOR FIVE PLOTTING PLANS (REDUCED TO A BASIS OF 20 x 20 LINKS)

Year	Crop	Plot 20 x 20 Links			Plot 20 x 100 Links	
		(a) Wholly at random in area 700 x 100 links	(b) At random within blocks 100 x 100 links	(c) At random in 5x5 latin squares 100 x 100 links	(d) Wholly at random in area 700 x 100 links	(e) At random in blocks 100 x 100 links
RANGE 2.						
1922	Maize	82,404.	61,675.	32,330.	48,673.	30,698.
1923	Maize	254,780.	155,109.	47,478.	153,148.	55,441.
1924	Maize	111,978.	84,419.	33,803.	55,968.	30,092.
1925	Maize	84,515.	79,559.	32,442.	25,117.	20,930.
1926	Maize	100,960.	85,540.	29,398.	47,721.	35,116.
1927	Oats				.2825	.1495
1928	Clover				1.9027	2.0850
1929	Timothy				2.2191	.4184
1930	Maize				.8083	.2850
1931	Oats				.7949	.4433
1932	Clover				1.9324	.6481
Ave. 5 years 1922-26	Maize				35,925.	24,951.
RANGE 3						
1922	Oats	185,031.	61,390.	23,669.	148,215.	23,675.
1923	Oats	154,784.	77,351.	31,446.	108,496.	32,192.
1924	Oats	252,451.	102,424.	36,309.	189,787.	39,603.
1926	Oats	472,088.	234,491.	68,467.	295,388.	53,337.
1927	Maize				.4747	.1685
1928	Oats				.2504	.1801
1929	Clover				5.1693	1.5702
1930	Timothy				.7077	.2329
1931	Maize				1.4487	.8690
1932	Oats				.7186	.2160
Ave. 4 years 1922-26	Oats				59,695.	10,033.
RANGE 4						
1924	Alfalfa	19.341	10.249	3.6866	12.1490	3.0168
1925	Alfalfa	14.234	4.904	2.2528	10.8106	1.3219
1926	Mangels	4.236	3.386	2.294	1.5567	.6886
1928	Maize				.2662	.1700
1929	Oats				.4027	.1023
1930	Clover				3.0507	.7519
1932	Maize				1.1723	.2608
RANGE 5						
1924	Oats	134,472.	110,743.	42,809.	51,193.	27,577.
1925	Oats	289,026.	146,731.	65,499.	200,652.	58,468.
1926	Oats	131,714.	126,315.	63,011.	30,715.	25,111.
1927	Mangels	8.6220	5.8782	4.437	4.3497	1.5823
1928	Oats				.2309	.1198
1929	Maize				.9987	.5897
1930	Oats				.2467	.1232
1931	Clover				1.3555	.6660
1932	Timothy				4.6373	.6824

2. RELATIVE PRECISION OF FIVE DIFFERENT PLOTTING PLANS WHEN SINGLE PLOTS ARE USED

More important than the differences in the error variances in different years and with the same crop on different ranges is the relation of the variances of the different methods of plotting to one another in the same year, on the same range, and with the same crop. A comparison of these error variances will show how much of the total variation has been eliminated, or the amount of improvement that has been made by dividing the area into blocks, rows, and columns, by using different plans of plotting.

Taking the variance for error of one of the plotting plans as a standard, a very good measure of the relative precision of the different plans may be obtained by dividing their error variances into that for the standard chosen. The relative precision of the standard plan will then be one, and the other plans will show higher or lower precision according as the variance for their errors is lower or higher respectively, than that for the standard.

In this case it will be best to take plots 20 × 100 links distributed at random as the standard, since this size of plot is represented in all years, and the method involves the range as a whole without division into blocks or parts in any way. The relative precision measured in this way for each of the five plotting plans is given in Table 3 for all ranges and for all years.

An examination of this data shows that, even on the same range and with the same crop, there is a very considerable difference in the relative precisions of each different plotting plan in the different years. On range 2, for example, the relative precision of plots 20 × 20 links in a 5 × 5 latin square is 3.22 in 1923, whereas in 1925 it is 0.77; that is, it is over four times as precise in 1923 as in 1925. On range 5 the relative precision of plots 20 × 20 links in a 5 × 5 latin square in 1925 (3.06) is over six times what it is in 1926 (.49). The means of the yearly relative precisions for the five different methods of plotting for each of the four ranges are given in Table 4.

This table shows that on this area of land when single plots are considered, plots 20 × 100 links distributed at random in blocks 100 × 100 links are in general more precise than any of the other methods tried. They are, on the average, a little over three times as precise as plots of the same size distributed wholly at random. Single plots 20 × 20 links in a 5 × 5 latin square are about 2.7 times as precise, single plots of the same size located at random within blocks 100 × 100 links appear to be about as precise, and single plots of the same size distributed wholly at random appear to be about half as precise as plots 20 × 100 distributed at random over the whole area.

TABLE 3. RELATIVE PRECISION OF SINGLE PLOTS FOR FIVE DIFFERENT PLOTTING PLANS

Year	Crop	Plots 20 x 20 Links			Plots 20 x 100 Links	
		(a) Wholly at random in area 700 x 100 links	(b) At random within blocks 100 x 100 links	(c) At random in 5x5 latin squares 100 x 100 links	(d) Wholly at random in area 700 x 100 links	(e) At random in blocks 100 x 100 links
RANGE 2						
1922	Maize	0.59	0.79	1.50	1.0	1.58
1923	Maize	.60	.99	3.22	1.0	2.76
1924	Maize	.50	.66	1.65	1.0	1.86
1925	Maize	.30	.31	.77	1.0	1.20
1926	Maize	.47	.56	1.62	1.0	1.36
1927	Oats				1.0	1.89
1928	Clover				1.0	.91
1929	Timothy				1.0	5.30
1930	Maize				1.0	2.84
1931	Oats				1.0	1.79
1932	Clover				1.0	2.98
Ave. 5 years 1922-26	Maize				1.0	1.44
RANGE 3						
1922	Oats	.80	2.41	6.26	1.0	6.26
1923	Oats	.70	1.40	3.45	1.0	3.37
1924	Oats	.75	1.85	5.23	1.0	4.79
1926	Oats	.62	1.26	4.31	1.0	5.53
1927	Maize				1.0	2.82
1928	Oats				1.0	1.39
1929	Clover				1.0	3.29
1930	Timothy				1.0	3.04
1931	Maize				1.0	1.67
1932	Oats				1.0	3.33
Ave. 4 years 1922, 23, 24, 26	Oats				1.0	5.94
RANGE 4						
1924	Alfalfa	.63	1.18	3.29	1.0	4.03
1925	Alfalfa	.76	2.20	4.80	1.0	8.18
1926	Mangels	.37	.46	.68	1.0	2.26
1928	Maize				1.0	1.56
1929	Oats				1.0	3.94
1930	Clover				1.0	4.06
1932	Maize				1.0	4.49
RANGE 5						
1924	Oats	.38	.46	1.19	1.0	1.86
1925	Oats	.69	1.37	3.06	1.0	3.43
1926	Oats	.23	.24	.49	1.0	1.22
1927	Mangels	.50	.74	.98	1.0	2.75
1928	Oats				1.0	1.93
1929	Maize				1.0	1.69
1930	Oats				1.0	2.00
1931	Clover				1.0	2.03
1932	Timothy				1.0	6.79

TABLE 4. MEAN RELATIVE PRECISION OF SINGLE PLOTS FOR FIVE PLANS OF PLOTTING ON FOUR RANGES

Range	Plots 20 x 20 Links			Plots 20 x 100 Links	
	(a) Wholly at random in area 700 x 100 links	(b) At random within blocks 100 x 100 links	(c) At random in 5x5 latin squares 100 x 100 links	(d) Wholly at random in area 700 x 100 links	(e) At random in blocks 100 x 100 links
2	0.49	0.66	1.75	1.0	2.22
3	.71	1.73	4.81	1.0	3.55
4	.58	1.28	2.92	1.0	4.07
5	.45	.70	1.43	1.0	2.96
Grand Average	.55	1.09	2.72	1.0	3.20

An examination of the data, however, shows that there are distinct differences in the relative precision of the several plotting plans on the different ranges. This indicates that the relative precision varies with the land, and that the grand average is not of general application.

3. RELATIVE PRECISION OF FIVE DIFFERENT PLOTTING PLANS WHEN PLOTS ARE REPLICATED SO AS TO USE THE SAME AREA OF LAND IN EACH CASE

As previously pointed out, the relative precisions given in the above tables were determined from the error variances of single plots. When allowance is made for the fact that single plots 20 $\times$ 20 links admit of fivefold replication on the same area as single plots 20 $\times$ 100 links, the relative precisions of the former must be multiplied by five. When this is done, the precision of the plotting plans where plots 20 $\times$ 20 links are used becomes very much better in relation to those in which plots 20 $\times$ 100 are used.

TABLE 5. MEAN RELATIVE PRECISION OF FIVE DIFFERENT PLANS OF PLOTTING IN WHICH THE SAME AREA OF LAND IS USED

Range	Plots 20 x 20 Links			Plots 20 x 100 Links	
	(a) Wholly at random in area 700 x 100 links	(b) At random within blocks 100 x 100 links	(c) At random in 5 x 5 latin squares 100 x 100 links	(d) Wholly at random in area 700 x 100 links	(e) At random in blocks 100 x 100 links
2	2.45	3.30	8.75	1.0	2.22
3	3.55	8.60	24.05	1.0	3.55
4	2.90	6.40	14.60	1.0	4.07
5	2.25	3.51	7.15	1.0	2.96
Grand Average	2.75	5.45	13.63	1.0	3.20

To make this point clear, it will suffice to consider the averages for each range. The data in Table 4, which contains the averages of the four ranges, has been recalculated in Table 5 to show the relative precision of the different plans of plotting when equal areas of land are used.

When the different methods are put on to this basis, plots 20 × 20 links in a latin square are much more precise than any of the other methods tried, being on the average nearly fourteen times as precise as plots 20 × 100 wholly at random. Plots 20 × 20 links at random in blocks stand next in efficiency, being 5.45 times as precise. Plots 20 × 20 links wholly at random and those 20 × 100 links at random in blocks 100 × 100 links are not widely different, being respectively 2.75 and 3.20 times as precise as plots 20 × 100 links distributed at random. Since this table is calculated from Table 4, the differences between the precision of the different ranges are equally marked, and it is better to consider the results obtained on the different ranges rather than to use the grand average.

4. CORRELATION BETWEEN PRELIMINARY AND SUBSEQUENT YIELDS

Having considered the original variation in the area, as measured by the error variances of several different plotting plans, and having discussed the influence of these plotting plans on the relative precision, we may now turn to a study of the relationship between the preliminary yields and the subsequent or experimental yields. As pointed out, this relationship has been measured by the regression coefficient. Since, however, the regression coefficient with some crops is expressed in pounds, and others in grams, and still others in decagrammes, and moreover, since the yields of different crops are very different, the regression coefficient does not lend itself to a comparison of relationships. The correlation coefficient which measures intensity of relationship provides a better means of comparison. Correlation coefficients, therefore, have been calculated from all the supposed preliminary and subsequent yields, corresponding to all years for which the relative precision of adjustment was obtained. These are given in Table 6 and represent those calculated from the remainders after eliminating the effects of rows, columns, and blocks, as the case may be.

The significance or non-significance of these coefficients has been measured by comparing them with those required for $P = .05$ and $P = .01$ as given by Fisher in Table V.A. Those which reach the level required for $P = .05$, are indicated by an asterisk, while those which also reach that required for $P = .01$ have a double asterisk.

An examination of the data obtained from plots 20 × 20 links shows that where the plots are assumed to be distributed wholly at random, out of a total of 12 correlation coefficients obtained only two are non-significant as measured by $P = .05$, and all the remaining ones are higher than that corresponding to $P = .01$. When the plots are assumed to be distributed

at random within blocks 100 × 100 links, out of 12 correlation coefficients two are non-significant, ten are significant as measured by P = .05, and 8 are significant as measured by P = .01. When the plots are assumed to be arranged in a 5 × 5 latin square, out of 12 correlation six are non-significant, six reach the standard for P = .05, and three reach the standard for P = .01.

When plots 20 × 100 links are used and are assumed to be distributed at random over the whole area, out of 49 correlations 19 are not significant, 30 reach the standard required for P = .05, and 21 reach the standard required for P = .01. Assuming the plots to be distributed at random within blocks, 28 correlations out of the 49 are not significant, 21 reach the standard required for P = .05, and 14 reach the standard required for P = .01.

In general, the correlation coefficients are much reduced when the planting plan is such as to provide for local control. This is true when the land is divided into blocks, but it is especially noticeable when the latin square arrangement is used. The proportionate number of significant correlations is thus less where the greatest local control is effected. This would seem to indicate that major soil differences are more permanent than intra-block variations, which fluctuate considerably from year to year.

Of a total of 134 correlation coefficients obtained, 13 only are negative, and of these three reach the standard required for P = .05. These significant negative correlations were all obtained on range 3 when the oat yields of 1922 were correlated with those of 1923. All five correlations determined between these two years on this range were negative, although two of them did not reach the standard required for significance.

A possible explanation of these negative correlations is to be found in the weather records. Taking the months of April, May, June, and July, the months involved in the growth of the oat crop, the average precipitation per month was 4.25 and 2.55 for 1922 and 1923 respectively, while the respective average temperatures were 58.0° and 55.1° Fahrenheit. This shows that 1922 was comparatively warm and wet, while 1923 was comparatively cold and dry. These rather widely different conditions may have caused different parts of the field to react differently in the two years so that areas producing a relatively high yield one year produced a relatively low yield the next, and vice versa.

5. ADJUSTED ERROR VARIANCES AND THEIR RELATIVE PRECISION

While a study of the correlation coefficients shows the relationship in the different cases, the important and practical point is the determination of the improvement in precision that is attainable by the use of the preliminary data in adjusting yields. We shall now turn to a study of this gain in precision.

TABLE 6. CORRELATION COEFFICIENTS FOR PRELIMINARY AND SUBSEQUENT YIELDS (APPLICABLE TO REMAINDER OR ERROR)

Preliminary Period	Subsequent Period	Plots 20x20 Links			Plots 20x100 Links	
		(a) Wholly at random in area 100 x 700 links	(b) At random within blocks 100 x 100 links	(c) At random in 5x5 latin squares 100 x 100	(d) Wholly at random in area 100 x 700 links	(e) At random in blocks of 100 x 100 links
RANGE 2						
1922 maize	1923 maize	0.265**	0.212*	0.155	0.450**	0.589**
1923 maize	1924 maize	.444**	.591**	.202*	.391*	.777**
1924 maize	1925 maize	.625**	.619**	.248*	.796**	.860**
1925 maize	1926 maize	.641**	.634**	.445**	.686**	.665**
1926 maize	1927 oats				.184	.307
1927 oats	1928 clover				.385*	.310
1928 clover	1929 timothy				.285	.401*
1929 timothy	1930 maize				.208	.136
1930 maize	1931 oats				.001	.160
1931 oats	1932 clover				.619**	.566**
Ave. 5 years						
1922-26 maize	1927 oats				.442*	.348
do	1928 clover				.148	.215
do	1929 timothy				.280	.573**
do	1930 maize				.159	.263
do	1931 oats				.381*	.577**
do	1932 clover				.367*	.724**
1928 clover	1932 clover				.148	.116
1927 oats	1931 oats				.673**	.494**
1926 maize	1930 maize				.241	.456*
RANGE 3						
1922 oats	1923 oats	—.343**	—.273**	—.125	—.386*	—.354
1923 oats	1924 oats	.569**	.377**	.054	.655**	.409*
1924 oats	1926 oats	.697**	.505**	.318**	.781**	.415*
1926 oats	1927 maize				.706**	.204
1927 maize	1928 oats				.438*	.272

1930	timothy	1931	maize				.232	.300
1931	maize	1932	oats				.680**	.598**
Ave. of 1922-23, 24, 26 oats		1927	maize				.674**	.082
do		1928	oats				.162	.087
do		1929	clover				.279	.265
do		1930	timothy				—.053	.150
do		1931	maize				.123	.436*
do		1932	oats				.190	.654**
RANGE 4								
1924	alfalfa	1925	alfalfa	.647**	.545**	.284**	.651**	.174
1925	alfalfa	1926	mangels	.406**	.194*	—.051	.660**	.331
1926	mangels	1928	maize				.468**	—.045
1928	maize	1929	oats				.509**	.020
1929	oats	1930	clover				.748**	.303
1930	clover	1932	maize				.716**	.300
1928	maize	1932	maize				.465**	.131
RANGE 5								
1924	oats	1925	oats	.351**	.286**	.004	.544**	.603**
1925	oats	1926	oats	—.063	—.069	.229*	.000	.098
1926	oats	1927	mangels	—.001	.001	—.107	.044	.179
1927	mangels	1928	oats				.531*	.442*
1928	oats	1929	maize				.448*	.234
1929	maize	1930	oats				.588**	.571**
1930	oats	1931	clover				.787**	.565**
1931	clover	1932	timothy				.728**	.471*
Correlation coefficients for P=.05‡				.194	.194	.194	.349	.381
Correlation coefficients for P=.01‡				.254	.254	.254	.449	.487
Degrees of freedom for ranges 2, 3, and 4				173	167	111	33	27
Degrees of freedom for range 5				123	119	79	23	19

*Indicates significance as measured by P=.05.

**Indicates significance as measured by P=.01.

‡=Taken from Fisher's Table V. A using n closest to the actual number of degrees of freedom. For range 5 on account of the different number of degrees of freedom, these figures do not apply. See Table V. A for P values corresponding to P=.05 and P=.01 for appropriate degrees of freedom for this range.

TABLE 7. ERROR VARIANCE OF SINGLE PLOTS AFTER ADJUSTMENT BY REGRESSION FOR PRELIMINARY TRIALS FOR FIVE DIFFERENT PLOTTING PLANS (REDUCED TO A BASIS OF 20 x 20 LINKS)

Preliminary Period	Subsequent Period	Plots 20x20 Links			Plots 20x100 Links	
		(a) Wholly at random in area 100 x 700 links	(b) At random within blocks 100 x 100 links	(c) At random in 5x5 latin squares 100x100	(d) Wholly at random in area 100 x 100 links	(e) At random in blocks of 100 x 100 links
RANGE 2						
1922 maize	1923 maize	238,284.	149,041.	46,756.	125,873.	37,519.
1923 maize	1924 maize	90,395.	55,290.	32,715.	48,871.	12,349.
1924 maize	1925 maize	51,844.	49,337.	30,713.	9,515.	5,638.
1925 maize	1926 maize	59,791.	51,445.	23,793.	25,992.	20,319.
1926 maize	1927 oats				.281	.140
1927 oats	1928 clover				1.771	1.841
1928 clover	1929 timothy				2.101	.364
1929 timothy	1930 maize				.797	.290
1930 maize	1931 oats				.819	.441
1931 oats	1932 clover				1.228	.456
Ave. 5 years						
1922-26 maize	1927 oats				.234	.136
do	1928 clover				1.917	2.063
do	1929 timothy				2.108	.291
do	1930 maize				.812	.275
do	1931 oats				.700	.306
do	1932 clover				1.723	.320
1927 oats	1931 oats				.447	.347
1928 clover	1932 clover				1.947	.663
1926 maize	1930 maize				.784	.234
RANGE 3						
1922 oats	1923 oats	137,286	71,991	31,236.	95,112.	29,184.
1923 oats	1924 oats	171,555	88,334	36,527.	111,547.	34,178.

TABLE 7 (Cont'd)

1924	oats	1926	oats	243,569	175,617	62,087.	118,637.	45,698.
1926	oats	1927	maize				.245	.167
1927	maize	1928	oats				.208	.172
1928	oats	1929	clover				4.691	1.628
1929	clover	1930	timothy				.699	.227
1930	timothy	1931	maize				1.412	.820
1931	maize	1932	oats				.398	.144
Ave. 1922, 23, 24, 26	oats	1927	maize				.267	.173
do		1928	oats				.251	.185
do		1929	clover				4.910	1.513
do		1930	timothy				.727	.236
do		1931	maize				1.470	.729
do		1932	oats				.473	.128
RANGE 4								
1924	alfalfa	1925	alfalfa	8.307	3.468	2.089	6.406	1.329
1925	alfalfa	1926	mangels	3.557	3.278	2.309	.905	.636
1926	mangels	1928	maize				.214	.176
1928	maize	1929	oats				.307	.106
1929	oats	1930	clover				1.383	.708
1930	clover	1932	maize				.589	.246
1928	maize	1932	maize				.946	.265
RANGE 5								
1924	oats	1925	oats	255,480	135,805	66,326.	147,360.	39,120.
1925	oats	1926	oats	132,258	126.762	60,442.	32,050.	26,177.
1926	oats	1927	mangels	8.690	5.927	4.440	4.530	1.612
1927	mangels	1928	oats				.173	.101
1928	oats	1929	maize				.833	.586
1929	maize	1930	oats				.169	.087
1930	oats	1931	clover				.538	.477
1931	clover	1932	timothy				2.274	.558

The variances for error or remainder for the unadjusted yields for each of the several plotting plans have been calculated and presented earlier. The corresponding adjusted variances have been calculated as previously described, and are presented in Table 7. It is now necessary to obtain a satisfactory measure of their relative precision. The unadjusted variance for error is the best basis for obtaining a measure of this precision. If we divide each error variance of the unadjusted yields by the corresponding error variance for adjusted yields, we shall have the best measure of the relative precision possible. The relative precision for the unadjusted yields will then be one in each case, and the improvement by adjustment will be measured by the departures of the relative precision of adjusted yields from this. When determined in this way, the relative precision gives us the number of replications required in the experimental year to be equal to the improvement in precision that has been made by adjustment for preliminary yields.

If only one year's work is to be involved in an experiment, it is almost as easy, apart from the distribution of labour and expense, to replicate the experiment in the year of the trial as it is to carry on a preliminary uniformity test. The relative precision obtained by a preliminary uniformity test to be of much value, therefore, should be two or more, that is to say, a gain of one or more. However, if an experiment is to be run over a period of years, and the differences in the soil are permanent ones so that improvement is obtained for several years following a preliminary test, it is only necessary for the improvement in the several years to total up to one or more.

Preliminary tests in such cases may be worth while even though a relative precision of two is not attained in any one year. Similarly, if a preliminary test is carried on for several years, e.g., five years, to be worth while it will be necessary for the total improvement in later experiments to total up to five or more. It will be convenient to summarize the data showing the relative precision and to discuss the results range by range.

a. Relative Precision Attained by Adjustment on Range 2

The data giving the relative precisions of adjustment on this range are to be found in Table 8. Considering first of all the plots 20 × 20 links where the data for two consecutive years represent preliminary and subsequent trials, there is no case where the increased precision justifies the extra work involved. Some improvement is made where the plots are distributed wholly at random and at random in blocks, but it is not worth while; and where the plan of planting is a latin square there is only a very slight improvement.

In the plots 20 × 100 links there are three cases where consecutive years are studied in which the relative precision is above two. Again, the

TABLE 8. RELATIVE PRECISION ATTAINED ON RANGE 2 BY THE ADJUSTMENT OF SUBSEQUENT OR EXPERIMENTAL YIELDS FOR THEIR PRELIMINARY YIELDS BY MEANS OF REGRESSION.

Preliminary Period	Subsequent Period	Plots 20 x 20 Links (a) Wholly at random in area 100 x 700 links	(b) at random within blocks 100 x 100 links	(c) at random in 5 x 5 latin squares 100 x 100 links	Plots 20 x100 Links (d) Wholly at random in area 100 x 700 links	(e) at random in blocks 100 x 100 links
1922 maize	1923 maize	1.069	1.041	1.015	1.217	1.478
1923 maize	1924 maize	1.239	1.527	1.033	1.145	2.437
1924 maize	1925 maize	1.630	1.612	1.056	2.639	3.712
1925 maize	1926 maize	1.688	1.663	1.235	1.836	1.728
1926 maize	1927 oats				1.004	1.065
1927 oats	1928 clover				1.074	1.132
1928 clover	1929 timothy				1.056	1.149
1929 timothy	1930 maize				1.014	.982
1930 maize	1931 oats				.971	1.004
1931 oats	1932 clover				1.574	1.420
Ave. 5 years 1922-26 maize	1927 oats				1.206	1.098
do	1928 clover				.992	1.011
do	1929 timothy				1.053	1.436
do	1930 maize				.996	1.036
do	1931 oats				1.153	1.446
do	1932 clover				1.121	2.025
1927 oats	1931 oats				1.776	1.276
1928 clover	1932 clover				.992	.977
1926 maize	1930 maize				1.030	1.218

use of the 1927 yields of oats for adjusting the yields of oats four years later in 1931 increased the precision by 77 per cent when the plots were distributed throughout the whole area.

Where the average yields of maize for five years, 1922 to 1926 inclusive, were used as a basis for adjusting subsequent yields in later years, the highest relative precision attained is 2.02 when they are used to adjust the 1932 trial data. If we add up all the changes in precision brought about by the adjustment of yields on the basis of the data of five maize crops, the totals are found to be 0.503 and 2.052 respectively for plots wholly at ndom, and at random in blocks 20 X 100 links. To be worth the prelimary work, the total of improvement should add up to 5.00.

Relative Precision Attained by Adjustment on Range 3

The results obtained from range 3 are given in Table 9. On this nge, dealing first with plots 20 X 20 links, only where the 1924 oat lds are used to adjust the oat yields of 1926 and the plots are distributed

wholly at random, is there an approach to sufficient improvement to be as efficient as the use of the same amount of land in the year of trial. Where the land is divided into blocks there is only slight improvement, and where latin squares are used, there is practically none at all.

TABLE 9. RELATIVE PRECISION ATTAINED ON RANGE 3 BY THE ADJUSTMENT OF SUBSEQUENT OR EXPERIMENTAL YIELDS FOR THEIR PRELIMINARY YIELDS BY MEANS OF REGRESSION.

		Plots 20 x 20 Links			Plots 20 x100 Links	
Preliminary Period	Subsequent Period	(a) Wholly at random in area 100 x 700 links	(b) At random within blocks 100 x 100 links	(c) At random in 5 x 5 latin squares 100 x 100 links	(d) Wholly at random in area 100 x 700 links	(e) at random in blocks 100 x 100 links
1922 oats	1923 oats	1.127	1.074	1.007	1.141	1.103
1923 oats	1924 oats	1.471	1.159	.994	1.701	1.159
1924 oats	1926 oats	1.938	1.335	1.103	2.490	1.167
1926 oats	1927 maize			—	1.937	1.006
1927 maize	1928 oats				1.202	1.043
1928 oats	1929 clover				1.102	.964
1929 clover	1930 timothy				1.013	1.025
1930 timothy	1931 maize				1.026	1.060
1931 maize	1932 oats				1.807	1.501
Ave. 1922, 23, 24, 26 Oats						
do	1927 maize				1.780	.971
do	1928 oats				.997	.972
do	1929 clover				1.053	1.037
do	1930 timothy				.973	.987
do	1931 maize				.985	1.191
do	1932 oats				1.519	1.688

When plots 20 × 100 links in size and data for single years are used for adjustment, the precision of the 1926 yields of oats is increased by 149 per cent by using the 1924 yields of oats to adjust them when the plots are distributed wholly at random, but when they are distributed at random in blocks there is only a slight increase in precision. In two other cases, namely, when the 1926 and 1931 yields are used for adjusting the 1927 and 1932 results respectively, the increase in relative precision is raised to close to 2 when the plots are distributed at random, but, again, when the land is divided into blocks the relative precision is much less. When four years of oats, 1922, '23, '24, '26, are used to adjust each of the yearly yields which follow, only with the yields of maize in 1927 and of oats in 1932 is there improvement at all. In the former cases the increase of precision disappears when the land is divided into blocks, but in the latter it is slightly increased. Since four years of preliminary work are involved, to be worth while the improvement by adjustment should total four or more.

c. Relative Precision Attained by Adjustment on Range 4

On range 4, the data for two years, 1927 and 1931, are missing. Where possible the yields of each year were adjusted on those of the one preceding it. The 1928 yields were adjusted on the basis of those of 1926, and the 1932 yields were adjusted on those of 1930. In addition, the 1932 maize yields were adjusted on the basis of the 1928 yields of maize, that is, the yield four years previous. The results are presented in Table 10.

TABLE 10. RELATIVE PRECISION ATTAINED ON RANGE 4 BY THE ADJUSTMENT OF SUBSEQUENT OR EXPERIMENTAL YIELDS FOR THEIR PRELIMINARY YIELDS BY MEANS OF REGRESSION

Preliminary Period	Subsequent Period	Plots 20 x 20 Links			Plots 20 x 100 Links	
		(a) Wholly at random in area 100 x 700 links	(b) At random within blocks 100 x 100 links	(c) At random in 5 x 5 latin squares 100 x 100 links	(d) Wholly at random in area 100 x 700 links	(e) at random in blocks 100 x 100 links.
1924 alfalfa	1925 alfalfa	1.713	1.414	1.078	1.688	.995
1925 alfalfa	1926 mangels	1.191	1.033	.993	1.720	1.083
1926 mangels	1928 maize				1.243	.966
1928 maize	1929 oats				1.309	.964
1929 oats	1930 clover				2.206	1.062
1930 clover	1932 maize				1.991	1.060
1928 maize	1932 maize				1.239	.981

In plots 20 × 20 there is no case where the improvement is equal to the duplication of the experiment in the year of the trial. In plots 20 × 100 links when the yields of the year previous are used for adjustment, in one case, that is when the 1929 oat yields are used for correcting the clover yields in 1930, there is a worth while correction, or an increase in precision of 120 percent where plots are located at random. Again, under the same method of planting, there is an improvement in precision of 99 per cent, when the clover crop of 1930 is used for adjusting the maize crop of 1932. This very closely approaches the improvement required to be equal to the duplication of the experiment in the year of the trials. When it is assumed that the treatments are planted at random in blocks of 100 × 100 links, in no case is there any worth while improvement.

d. Relative Precision Attained by Adjustment on Range 5

The results obtained from range 5 are presented in Table 11. On this range where plots 20 × 20 links were studied there were no important improvements in precision in any case.

TABLE 11. RELATIVE PRECISION ATTAINED ON RANGE 5 BY THE ADJUSTMENT OF SUBSEQUENT OR EXPERIMENTAL YIELDS FOR THEIR PRELIMINARY YIELDS BY MEANS OF REGRESSION

Preliminary Period	Subsequent Period	Plots 20 x 20 Links: (a) Wholly at random in area 100 x 500 links	(b) At random within blocks 100 x 100 links	(c) At random in 5 x 5 latin squares 100 x 100 links	Plots 20 x 100 Links: (d) Wholly at random in area 100 x 500 links	(e) at random in blocks 100 x 100 links
1924 oats	1925 oats	1.131	1.080	.987	1.362	1.494
1925 oats	1926 oats	.996	.996	1.042	.958	.959
1926 oats	1927 mangels	.992	.992	.999	.960	.982
1927 mangels	1928 oats				1.336.	1.181
1928 oats	1929 maize				1.199	1.005
1929 maize	1930 oats				1.465	1.410
1930 oats	1931 clover				2.521	1.397
1931 clover	1932 timothy				2.039	1.222

In plots 20 × 100 where the treatments were assumed to be distributed at random over the area, an increase in precision of 152 per cent was obtained when the 1930 yields of oats were used to adjust the 1931 yields of clover; and an increase of 103 per cent was attained when the 1931 yields of clover were used to adjust the 1932 yields of timothy. No other improvements of a worth while nature are to be found.

6. COMPARISON OF THE RELATIVE PRECISION ATTAINED BY ADJUSTMENT IN DIFFERENT WAYS

a. Adjustment by Single Years Versus a Period of Years

Having considered the improvement in the relative precision attained by adjustment for previous yields on the several ranges, it is worth while to examine these data further to compare several possible bases for adjustment. One can compare the precision attained when single years are used for adjustment with that when the average of four or five years is used for this purpose. This can be done best on ranges 2 and 3 using plots 20 × 100 wholly at random, by comparing the precisions attained by adjusting the yields of the crops of 1927 to 1932 inclusive by means of single years immediately preceding the trial years, with those attained by adjusting the same yearly yields by means of the average of five years of maize and four years of oats, respectively, on the two ranges.

Both when single years and when an average of several years (five of maize and four of oats in this case) are used for adjustment, there is a very great deal of variation in the relative precision attained. When single years are used, it ranges from 0.971 to 1.937; and when a period of years is used, it ranges from 0.973 to 1.780. If we take the average relative

precision attained for the six years in question, when adjusted for single years and for an average of a period of years, we find that on range 2 it is 1.115 and 1.084 respectively. On range 3 the corresponding averages are 1.348 and 1.218 respectively. While single years thus appear to be on the average a little more precise than a period of four or five years for adjustment, in view of the variation in the different results these differences cannot be considered as significant. There is, moreover, one apparent complicating factor which should be mentioned, namely, that the averages of the four and five years used for adjustment were in latter cases farther removed from the year of the trial than was true where single years were used. This, however, is probably not important, as may be seen from what follows.

b. The Adjustment of a Crop Immediately Succeeding Versus One Several Years Later

One can also compare the relative precision attained by adjustment by means of a crop or crops immediately preceding with that obtained when adjustment is made by means of a crop several years previous. When single years are used as a basis for adjusting yields of an immediately succeeding year, the relative precision attained ranges from 0.958 (on range 5) to 3.712 (on range 2), whereas when single years are used for adjusting yields four years later, the relative precision ranges from 0.977 to 1.776 (both on range 2). When the average of several years is taken as a basis for adjustment, on range 2 the highest relative precision (2.025 is attained when the average of the five maize crops (1922-'26) is used for adjusting the yields of a crop six years later, namely, the 1932 crop of clover. On range 3, when the average of the four oat crops (1922-'26 with 1925 omitted) is used for adjustment, the highest relative precision (1.780) is attained when they are used to adjust the immediately succeeding crop, namely, maize in 1927. However, the next highest precision (1.519) was attained when the same data were used to adjust the yields of the oat crop of 1932, six years after the preliminary trial. There is thus no uniform trend to indicate whether a crop immediately preceding a trial is better as a means of adjustment than one a few years previous as might be expected.

c. Adjustment by Similar Crops Versus Dissimilar Ones

A further study can be made as to the relative utility of similar and dissimilar crops when used for adjustment. The highest relative precisions were obtained when the maize crop of 1924 was used for adjusting the yields of maize in 1925 on range 2. Again on range 3 a very high precision was attained when the oat crop of 1924 was used to adjust the yields of oats of 1926. On the other hand, some quite low precisions were obtained when the maize crops on range 2 and the oat crops on range 3 were

used as a means of adjusting the yields of subsequent similar crops. Furthermore, quite high relative precisions were obtained in several cases where a crop was used for adjusting the yields of a dissimilar crop. Examples of this are to be found on range 2 where the 1931 crop of oats was used for adjusting the 1932 yields of clover (1.574), on range 3 where the 1931 crop of maize was used for adjusting the yields of the 1932 crop of oats (1.807), on range 4 where oats in 1929 and clover in 1930 were used for adjusting the yields of clover (2.206) and maize (1.991) respectively, and on range 5 where oats in 1930 and clover in 1931 were used for adjusting the subsequent yields of clover (2.521) and timothy (2.039) respectively. In this instance also one cannot conclude that adjustment by means of previous yields gives greater precision where similar crops are used than it does where dissimilar crops are used.

It appears therefore that no definite conclusion can be drawn regarding the relative precision for adjustment purposes of,—(a) single years versus the average of several years, (b) proximity of preliminary trial to that of the subsequent trial, and (c) similar versus dissimilar crops. The effect of these is apparently overshadowed by other more important factors. The relative precision attained by adjustment by any method depends upon the relationship between the interactions of crops, soil, and weather conditions in the preliminary and subsequent trials. In this study the year effect and the interaction between year, soil, and crop is apparently greater than any differences that there may be between length of preliminary trial, proximity of preliminary trial to the subsequent trial, and the similarity or dissimilarity of crops.

7. RELATIVE PRECISION ATTAINED WHERE THE CORRELATION COEFFICIENTS FOR PRELIMINARY AND SUBSEQUENT YIELDS ARE NEGATIVE

It has been noted previously that in this study only three significant negative correlations were obtained, and they were all for the 1922 and 1923 oat crops on range 3. They were —0.343 for plots 20 × 20 links wholly at random, —0.273 for plots 20 × 20 links at random in blocks 100 × 100 links, and —0.386 for plots 20 × 100 links arranged wholly at random. The corresponding regression coefficients for the 1923 yields on those of 1922 were —0.314, —0.307, and —0.330 respectively. Although the regression coefficients are negative values, in the process of correction following the formula used, the negations disappear and the precision is increased exactly to the same extent as if the coefficients of correlation and regression coefficients had been positive. The relative precisions obtained in these instances were 1.127, 1.074 and 1.141 respectively. The greatest improvement is thus fourteen per cent, a value which is very low as compared with that which is necessary to make the preliminary work worth doing.

8. RELATIVE PRECISION ATTAINED BY ADJUSTMENT FOR PREVIOUS YIELDS COMPARED WITH THAT ATTAINED BY LOCAL CONTROL

In a previous part of this bulletin, five different plotting plans involving two different sizes of plots were compared as to the relative precision (without adjustment for previous yields) when single plots are used, and also when the plots of the two sizes are replicated so as to take up the same amount of land. It is appropriate to compare the precision obtained by adjustment for previous yields with that obtained by local control.

In the case of plots 20 × 100 links distributed wholly at random, since the error variances obtained without adjustment have been taken as having a relative precision of one in measuring the precision of the plotting plans, as well as in determining the precision obtained by adjustment for previous yields, one can compare directly the precision attained by adjustment for previous yields with that attained by local control.

Table 12 contains comparative relative precisions for each of the two methods, obtained by taking the average of the several results of single years on each of the four ranges. In the case of adjustment for previous information, the year immediately preceding the supposed experimental year was used where available, and when not available for any reason the year before that was used.

TABLE 12. A COMPARISON OF THE RELATIVE PRECISION ATTAINED BY ADJUSTMENT FOR THE YIELD OF A PREVIOUS YEAR, AND BY LOCAL CONTROL IN PLOTS 20 x 100 LINKS

Range		Relative Precision* Attained by: Adjustment for Yields of the Previous Year	Relative Precision* Attained by: Local Control Plots at Random in Blocks 100 x 100 Links
2	Mean of ten trials	1.35	2.27
3	Mean of nine trials	1.49	3.25
4	Mean of six trials	1.69	4.08
5	Mean of eight trials	1.48	2.73

*Relative precision of plots wholly at random without adjustment taken as 1.

It is clear from this that on these areas of land the division of land into blocks 100 × 100 links on the average is more effective in increasing the precision than is the adjustment of yields for yields obtained in a previous year.

In a somewhat similar manner it is possible to compare the relative precision obtained by local control, and by adjustment for previous information using plots 20 × 20 links. To do so it is best again to take single plots distributed at random over the whole area as a basis, having a relative precision of one. In this case, however, it is necessary to recalculate the relative precision of different plotting plans on to this basis from data in

Table 3. The relative precision of adjustment for previous yields, however, as given in Tables 8 to 11, was calculated, using the unadjusted variances as a basis for unity and can be used directly. In Table 13 are to be found the data by which the precision attained by adjustment may be compared with that attained by local control. They represent averages of several trials on each range. The adjustment in each trial was made by using the yields of the previous year for which data had been obtained.

TABLE 13. A COMPARISON OF THE RELATIVE PRECISION ATTAINED BY ADJUSTMENT FOR THE YIELD OF A PREVIOUS YEAR, AND BY LOCAL CONTROL IN PLOTS 20 x 20 LINKS

Range	Relative Precision* Attained by		
		Local Control Plots at Random in	
	Adjustment for Previous Trial	Blocks 100x100 Links	5 x 5 Latin Squares 100x100 Links
2 Mean of 4 years	1.406	1.298	3.670
3 Mean of 3 years	1.512	2.166	6.284
4 Mean of 2 years	1.452	2.069	4.077
5 Mean of 3 years	1.040	1.493	2.820

*Relative precision of plots distributed wholly at random without adjustment taken as 1.

With this size of plot, too, local control has been decidedly more effective in reducing the error variances and so increasing precision than has adjustment for previous yields by means of regression.

While it is clear that, under the conditions of this experiment, preliminary uniformity trials as a rule are far from being efficient in reducing the error variance of subsequent trials by means of regression, they may be useful for other purposes. From these tests it would appear that major soil differences are more permanent than the smaller differences between neighbouring plots, and furthermore on any given range the relative order of precision of different systems is generally the same from year to year. Preliminary trials may therefore be useful for determining the plotting plans that are likely to prove most efficient. Moreover, they may prove useful in eliminating areas that are unsuitable for experimental purposes.

F. SUMMARY

1. Four ranges of land, each approximately three-quarters of an acre in size, which had been uniformly treated for many years, were harvested by plots 20 × 20 links or 20 × 100 links over a period of nine to twelve years.

2. In the early years on each range one kind of crop was grown in successive years. In later years on all ranges the rotation followed was maize, oats, clover, timothy.

3. Error variances were calculated for the unadjusted yields of five different plotting plans.

4. On the same land and with the same crop there was found to be a very great difference in the variation in different years.

5. In the same year and with the same crop there was a great difference in the variation on different ranges of land in the same field.

6. The relative precision of single plots for the five different plotting plans was calculated. Taking single plots 20 × 100 links distributed wholly at random as a basis, and having a relative precision of one, the relative precision of single plots of the same size distributed at random in blocks 100 × 100 links, was found to be 3.20. Single plots 20 × 20 links distributed wholly at random, at random in blocks 100 × 100 links, and in latin squares 100 × 100 links gave relatively precisions of 0.55, 1.09, and 2.72 respectively.

7. A measure of the relative precision of plots 20 × 20 links, when replicated so as to take up the same area of land as plots 20 × 100 links, was obtained. Using the same basis as above, the relative precisions were: 2.75 when the plots were assumed to be distributed wholly at random, 5.45 when distributed at random in blocks 100 × 100 links, and 13.63 when they were in 5 × 5 latin squares of the same size.

8. Interannual correlations for yields of plots of the two sizes and different arrangements were calculated.

9. In the case of plots 20 × 20 links, out of 12 correlation coefficients obtained in each case, 10 are significant as measured by $P = .05$ when assumed to be distributed wholly at random; 10 reach significance when distributed at random in blocks 100 × 100 links; while 6 reach this standard when the plots are assumed to be arranged in a latin square.

10. In the case of plots 20 × 100 links, out of 49 correlations in each case, 30 reach the standard required for $P = .05$ when the plots are assumed to be distributed wholly at random; while 21 reach the same standard when the plots are assumed to be at random in blocks 100 × 100 links.

11. Out of a total of 134 correlation coefficients, 13 are negative, only three of which reach the value required for $P = .05$. All these are for the same range and for the same year.

12. In general, the correlation coefficients are much lower when the plots are assumed to be distributed at random within blocks than when they are similarly distributed over the whole range, but there is much variation in this regard.

13. The relative precision of subsequent or experimental yields adjusted by regression on preliminary yields was calculated for the five plotting plans studied.

14. There is much variation in the improvement of precision obtained by the adjustment of trial yields by regression on their preliminary yields, in the different years and periods, no matter what method of plotting is assumed.

15. In the case of plots 20 × 20 links, the relative precision attained by adjustment for previous yields ranges from 0.992 to 1.938. None reached the relative precision required to be equal to duplication in the year of the trial.

16. With plots 20 × 100 links, the relative precision attained by adjustment ranges from .958 to 3.712. Out of 98 values for relative precision only 8 had values above two. Five of these were obtained when the plots were assumed to be distributed wholly at random, and three were obtained when the plots were assumed to be distributed at random in blocks 100 × 100 links.

17. There is no consistent difference between the relative precision attained by adjustment when single yearly yields are compared with the average yields of four or five years as a basis for adjustment.

18. The proximity of the preliminary year to the trial year varies greatly in its effect on the precision attained. The highest relative precision was obtained where consecutive yearly yields were used, but quite high relative precisions were also obtained when the two crops were four years apart.

19. The highest relative precision was obtained when the preliminary and trial years involved the same crop. Dissimilar crops, however, also gave quite high relative precision in some instances.

20. In this study the year effect and the interaction between the year, soil, and crop is apparently greater than the other factors studied.

21. A negative correlation or regression coefficient is just as efficient in improving precision as a positive one of the same size. Of the three relative precisions obtained where the regression and correlation coefficients are negative and significant, the greatest improvement obtained is 14 per cent.

22. Both when plots 20 × 20 links, and those 20 × 100 links are used, much greater precision is obtained on the average by local control than by adjustment for previous yields. This is true without exception for all four ranges.

G. CONCLUSIONS

Under the conditions of this experiment the use of preliminary uniormity trials for the purpose of adjusting yields of subsequent experiments y regression is only rarely as effective in increasing precision as is the use f the same amount of land and labour in replicating the experiment in the ear of the trial. Preliminary uniformity trials may, however, be useful in letermining the plotting plans that will give the greatest precision. They nay also prove useful in eliminating areas that are unsuited for experinental purposes.

H. ACKNOWLEDGMENT

Professor L. C. Raymond, Professor E. A. Lods, and Mr. J. N. Bird have cooperated in collecting data and in assistance throughout the progress of this investigation. The analysis of the problem was commenced while the author was enjoying the hospitality of the Rothamsted Experiment Station, Harpenden, England, during which time he had the guidance and assistance of Dr. R. A. Fisher. Mr. J. W. Hopkins, of the National Research Council of Canada, has made many valuable suggestions regarding the statistical analysis and interpretation of results. Professor E. W. Crampton has made helpful criticisms of the manuscript. To all of these the author makes grateful acknowledgement. Finally, he desires to express great appreciation to Mr. W. F. Millinchamp for the large amount of painstaking, patient, work done in making the necessary calculations.

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APPENDIX

In the appendix is contained the temperature and precipitation records for the years 1922 to 1932, inclusive. As well, the yields of each plot are given for the duration of this experiment. It was from these data that the calculations included in the text of the bulletin were made.

AVERAGE MONTHLY TEMPERATURE AT MACDONALD COLLEGE, 1922-32 INCLUSIVE.
(DATA IN DEGREES FAHRENHEIT)

Month	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average 1922 to 1932	Average 1907 to 1932
January	10.15	8.25	13.52	6.55	13.28	14.80	15.20	12.80	16.40	12.25	24.50	13.43	12.88
February	14.60	6.90	7.14	21.35	12.71	16.90	13.15	15.82	15.09	16.35	15.60	14.15	12.93
March	29.40	18.20	29.40	31.00	20.10	30.55	24.70	28.60	26.16	32.15	20.95	26.47	25.34
April	42.05	38.50	40.10	42.60	34.65	42.20	35.95	40.40	40.05	45.95	36.95	39.94	40.33
May	57.55	53.10	50.30	50.50	51.65	52.25	53 70	52.05	56.50	56.05	53.80	53.40	54.01
June	64.65	64.30	63.00	64.80	59.90	61.15	62.66	62.45	67.65	64.95	62.90	63.49	63.71
July	67.90	64.50	68.70	64.75	67.40	67.75	69.35	67.60	68.10	72.00	66.10	67.65	69.27
August	65.50	64.33	68.10	68.00	66.05	63.80	69.50	64.35	65.50	67.20	67.15	66.32	66.35
September	60.30	58.25	56.65	57.50	57.50	60.05	54.75	59.65	60.25	60.55	59.25	58.61	58.38
October	45.00	48.29	48.75	40.20	45.35	49.55	47.30	45.15	49.00	49.00	46.45	46.73	47.48
November	35.25	35.50	36.39	33.50	34.50	36.10	34.50	34.30	37.71	38.40	28.45	34.96	33.54
December	17.55	29.40	15.45	19.73	15.55	21.35	24.06	16.41	22.20	21.05	22.93	20.52	19.74
Average April-September	59.66	57.16	57.81	58.02	56.19	57.87	57.65	57.75	59.67	61.11	57.69	58.23	58.67
Average for Year	42.49	40.79	41.46	41.71	39.89	43.04	42.07	41.63	43.72	44.66	42.08	42.14	42.00

Data from Horticultural Department, Macdonald College

PRECIPITATION AT MACDONALD COLLEGE, 1922-32, INCLUSIVE
(DATA IN INCHES OF RAINFALL)

Month	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	Average 1922 to 1932	Average 1907 to 1932
January	1.75	3.85	4.41	3.30	2.04	1.51	3.77	6.04	4.60	2.97	4.96	3.56	3.25
February	2.02	2.60	2.70	3.63	3.10	3.93	2.58	2.22	1.42	2.73	2.62	2.69	2.29
March	1.63	3.94	2.01	3.48	2.95	1.29	3.29	5.15	2.87	1.59	4.08	2.93	2.84
April	5.45	2.43	5.60	1.80	2.59	1.44	3.20	5.55	2.18	2.30	4.06	3.33	2.54
May	2.09	2.52	4.10	2.91	.98	4.33	3.64	2.90	3.79	2.72	1.36	2.85	2.97
June	6.29	2.59	1.48	3.21	3.78	3.04	3.08	6.10	4.52	3.46	2.19	3.61	3.15
July	3.16	2.65	4.31	3.50	3.08	3.93	5.33	.80	5.54	4.49	2.49	3.57	2.92
August	3.09	3.40	1.88	2.26	4.41	1.98	4.96	2.74	.88	1.50	3.52	2.78	2.97
September	1.46	2.11	7.16	7.65	3.12	1.41	4.92	1.30	1.61	6.64	2.88	3.66	3.48
October	3.63	3.52	.94	3.08	4.62	3.48	3.89	3.10	.78	2.56	5.59	3.20	3.08
November	1.21	4.73	2.85	3.13	3.66	9.07	4.91	2.44	2.39	2.72	4.18	3.75	3.85
December	1.77	3.26	3.11	4.10	1.62	4.62	2.81	2.80	1.46	2.96	2.95	2.86	2.62
Total April to September	21.54	15.70	24.53	21.33	17.96	16.13	25.13	19.39	18.52	21.11	16.50	19.80	18.03
Total for year	33.55	37.60	40.55	42.05	35.95	40.03	46.38	41.14	32.04	36.64	40.88	38.79	35.96

Data from Horticultural Department, Macdonald College

RANGE 2—1922—NORTH WESTERN DENT MAIZE
YIELD OF FODDER IN DECAGRAMMES PER PLOT

Plot No.	Plots 20 x 20 Links: Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	5984	6337	5588	5667	5511	29087
2	6248	5929	5736	5641	5873	29427
3	6111	5795	5414	5836	5689	28845
4	5758	5954	5559	5829	6001	29101
5	5713	5740	5062	5256	5303	27074
6	5655	5388	5400	5570	5398	27411
7	5771	6092	5726	5691	6146	29426
8	5833	6244	5861	5930	6058	29926
9	5978	6658	6072	6418	6172	31298
10	6108	6515	5974	6197	6291	31085
11	6236	6441	6134	6555	6196	31562
12	6184	6283	6052	6101	6301	30921
13	6336	6379	6055	6175	6396	31341
14	6272	6263	6452	6112	6308	31407
15	6145	6532	6103	6216	6138	31134
16	6337	6379	6016	6740	5929	31401
17	6211	6337	6164	5893	5883	30488
18	5812	6308	5928	5910	6052	30010
19	6645	5956	6129	6413	6049	31192
20	6267	6058	5920	5944	6028	30217
21	6338	6247	6183	5690	6401	30859
22	6594	6195	6295	5975	6491	31550
23	6113	6091	5862	5629	6131	29826
24	5868	5948	5968	5823	5555	29162
25	5986	6238	6034	5843	5975	30076
26	5571	6323	6016	5875	5875	29660
27	6173	5965	5661	5735	5908	29442
28	5911	6378	5961	5909	6042	30201
29	5855	5741	5926	6074	5803	29399
30	5723	5997	5929	5832	5917	29398
31	6032	6072	5875	6350	5920	30249
32	6038	6211	6249	5826	6064	30388
33	5867	5917	5795	5891	6216	29686
34	6009	6243	6312	5948	6242	30754
35	5841	5711	5631	5529	5977	28689

RANGE 2—1923—NORTH WESTERN DENT MAIZE
YIELD OF FODDER IN DECAGRAMMES PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	3575	3815	3946	3527	3502	18365
2	3329	*3531	3584	3830	3385	17659
3	3253	3709	3770	4233	3485	18450
4	3303	3626	3804	3621	3398	17752
5	3510	3666	3641	3667	3190	17674
6	2952	3308	3428	3676	3635	16999
7	2886	3564	3598	3934	4395	18377
8	3203	3878	4061	3932	4642	19716
9	3656	3844	4634	4886	4848	21868
10	3567	4254	4890	4844	4938	22493
11	3844	*4407	4907	4889	5124	23171
12	3648	*3566	4442	4681	4949	21286
13	3466	x2997	4005	4351	4341	19160
14	3536	3851	4038	4585	4106	20116
15	*3165	4531	4199	4328	4303	20526
16	3854	*3684	4482	4435	4043	20498
17	3905	4350	4216	4891	4069	21431
18	3953	4002	4169	4140	4026	20290
19	3894	4001	4306	4757	4212	21170
20	4135	4526	4064	4427	4411	21563
21	4193	4210	4171	3900	4335	20809
22	4092	4064	4001	4128	4344	20629
23	3540	3586	*3800	3862	3924	18712
24	3563	3243	3938	4283	4664	19691
25	3803	4311	4225	4399	4523	21261
26	*3645	4450	4616	4761	4353	21825
27	4112	4130	4568	4588	4510	21908
28	4019	4418	4380	4654	4395	21866
29	4244	4513	4734	4821	4482	22794
30	3943	4722	4506	4775	4253	22199
31	4894	4867	4815	4926	4798	24300
32	4712	4749	4646	4688	4609	23404
33	4407	4892	4662	4949	5037	23947
34	4327	4802	4536	4731	4914	23310
35	4405	4322	4678	4610	4608	22623

*=1 hill missing x=3 hills missing

RANGE 2—1924—NORTH WESTERN DENT MAIZE
YIELD OF FODDER IN DECAGRAMMES PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	3244	3539	3539	3403	3176	16901
2	3539	3993	3494	3743	3517	18286
3	3448	3948	3743	3721	3403	18263
4	3403	3993	3880	3743	3562	18581
5	3448	3789	3607	3585	3267	17696
6	3176	3766	3494	3630	3448	17514
7	3494	3789	3743	3970	3857	18853
8	3698	4038	3789	4197	4152	19874
9	3948	4129	4106	4084	3993	20260
10	4220	4311	4538	4492	4084	21645
11	4243	4174	3993	4991	4356	21757
12	3902	3993	4061	4311	4401	20668
13	3494	4129	3902	4220	4084	19829
14	3653	3948	3970	4356	3789	19716
15	3426	4265	4220	4152	3721	19784
16	3403	3471	3902	3811	3902	18489
17	3267	3448	3834	4038	3403	17990
18	2813	3131	3448	3653	3630	16675
19	2382	3426	3630	3857	3675	16970
20	3108	3471	3698	4016	3607	17900
21	3857	3993	3811	3925	4016	19602
22	4038	3857	3993	4038	3857	19783
23	3448	3766	4038	3562	3675	18489
24	3176	3675	4016	3857	3585	18309
25	3403	3789	3902	3948	4356	19398
26	3312	3698	3857	4152	4084	19103
27	3358	3766	3630	3880	3902	18536
28	3630	3585	3494	4129	3653	18491
29	3448	4038	3789	3902	3675	18852
30	3471	3834	3562	4084	3766	18717
31	3766	3948	3970	3880	3857	19421
32	3811	4061	3902	4129	*3607	19510
33	3675	3811	3925	*3562	3811	18784
34	3494	3675	3857	4129	4243	19398
35	3267	3698	3176	3902	3675	17718

*=1 hill missing.

RANGE 2—1925—NORTH WESTERN DENT MAIZE
YIELD OF FODDER IN DECAGRAMMES PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	3880	3721	4538	4084	3948	20171
2	4220	4651	4243	4152	4220	21486
3	4106	4606	4356	4447	3948	21463
4	4174	4379	4379	4469	3993	21394
5	4106	4447	4538	4174	3789	21054
6	3630	4084	4333	4379	4197	20623
7	3993	4469	4424	4401	4447	21734
8	3857	4538	4447	4401	4538	21781
9	4197	4538	4674	4810	4379	22598
10	4333	4674	4901	4855	4469	23232
11	4152	4651	4923	4832	4538	23096
12	4016	4401	4492	4288	4492	21689
13	3811	4447	4674	4515	4152	21599
14	3857	4243	4606	4243	3948	20897
15	3789	4311	4447	4265	4424	21236
16	3630	4560	4606	4333	4174	21303
17	3675	4401	4424	4311	3993	20804
18	3970	4197	4356	4061	3970	20554
19	3789	4106	*3993	4174	4152	20214
20	3902	4469	4311	4084	3766	20532
21	4424	4606	4311	3902	4288	21531
22	4220	4674	4742	4243	4174	22053
23	3970	4243	4538	3948	4401	21100
24	3630	*4016	4424	*4174	4696	20940
25	3630	4424	4538	4243	4538	21373
26	4129	4220	4356	4311	4379	21395
27	3857	4174	4696	4651	4538	21916
28	4106	4379	4447	4560	4424	21916
29	4106	4469	4696	4311	4379	21961
30	3857	4333	4356	4628	4469	21643
31	4401	4764	4832	4651	4515	23163
32	4311	4538	4560	4492	4538	22439
33	4084	4515	4333	4515	4311	21758
34	3811	4583	4356	4764	4469	21983
35	3630	3789	3970	4174	4560	20123

*=1 hill missing.

RANGE 2—1926—NORTH WESTERN DENT MAIZE
YIELD OF FODDER IN DECAGRAMMES PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	3902	4311	4288	3857	3698	20056
2	4129	4197	3880	4333	3880	20419
3	3766	4265	4016	4129	3948	20124
4	3811	4243	4288	3970	3630	19942
5	3857	4265	4084	3562	3448	19216
6	3290	3834	3675	4016	3675	18490
7	4084	4538	4016	4265	4265	21168
8	3789	4469	4311	4265	4492	21326
9	3970	4356	4333	4401	4197	21257
10	4016	4583	4379	4583	4424	21985
11	3698	4538	4356	4719	4288	21599
12	3698	4379	3993	4084	4220	20374
13	3630	3970	4016	4038	3948	19602
14	3630	4106	3925	3743	3585	18989
15	3494	4129	3698	3811	3653	18785
16	3562	3811	3948	4016	3539	18876
17	3630	4174	3857	3948	3630	19239
18	4038	4243	4174	3857	3721	20033
19	3857	4220	3948	3948	3811	19784
20	4401	4333	4129	3675	3585	20123
21	4379	4220	3880	3857	3857	20193
22	3811	3970	3811	3675	3902	19169
23	3630	3857	3517	3403	3517	17924
24	3448	3837	3970	3857	4084	19216
25	3948	4220	3857	4379	4174	20578
26	3653	4265	4152	4492	4220	20782
27	3675	3948	4016	4311	4106	20056
28	3766	4288	3970	4447	4129	20600
29	4038	4583	4197	4447	4311	21576
30	3857	4447	3993	4469	4333	21099
31	4492	4810	4492	4810	4356	22960
32	3743	4764	4311	4469	4356	21643
33	3630	4447	3811	4311	4651	20850
34	3743	4356	4220	4311	4447	21077
35	3585	4038	3948	4197	4379	20147

RANGE 2—PLOTS 20 x 100 LINKS (WEIGHTS IN POUNDS)

Plot No.	Oats Banner 44 1927	First Year Hay - 1928	Second Year Hay 1929	North Western Dent 1930	Oats Alaska 1931	First Year Hay 1932
1	45.5	173.95	78.14	72.23	39.5	67.71
2	50.0	190.20	78.33	75.24	44.0	68.38
3	48.0	182.39	77.91	76.10	45.5	68.34
4	45.5	185.72	77.06	79.64	45.5	65.90
5	49.0	180.66	78.73	79.96	45.0	66.01
6	45.5	179.56	79.28	81.03	45.0	64.92
7	51.0	179.51	76.70	84.88	47.0	70.27
8	56.0	188.13	85.81	84.27	51.5	77.57
9	52.5	179.73	84.45	83.43	53.0	83.72
10	51.0	189.81	92.05	83.84	51.5	83.13
11	51.5	188.11	91.52	81.91	51.5	84.80
12	51.0	176.83	89.84	84.32	47.0	82.11
13	50.5	183.81	89.51	83.51	46.0	78.43
14	51.0	182.55	90.02	80.09	45.5	81.72
15	51.5	177.14	92.41	76.94	47.0	81.35
16	52.0	177.61	92.30	72.97	51.0	79.33
17	53.5	176.52	95.36	74.08	51.0	88.19
18	54.5	196.41	96.60	79.05	53.5	81.74
19	54.0	188.16	95.60	74.46	55.5	80.33
20	53.0	177.44	96.78	72.38	56.5	80.63
21	54.0	188.88	81.36	73.50	57.5	78.95
22	54.5	189.06	73.75	71.26	52.5	71.51
23	52.0	181.31	74.37	70.58	46.0	70.07
24	54.0	183.52	78.64	73.55	47.5	72.89
25	51.0	165.32	76.18	78.25	45.5	69.56
26	52.5	171.76	76.03	78.13	46.0	69.47
27	49.5	171.83	72.34	74.05	44.0	69.80
28	50.0	172.00	74.72	75.98	45.5	66.47
29	51.5	186.31	77.83	72.87	47.0	65.76
30	50.0	185.33	80.22	74.13	37.0	64.68
31	51.5	184.33	85.56	76.26	51.0	70.78
32	56.0	182.30	86.51	74.49	52.5	71.93
33	53.0	177.96	85.07	69.96	49.0	71.17
34	54.0	196.42	86.58	75.18	50.5	70.11
35	54.0	181.98	77.90	70.36	46.5	65.02

RANGE 3—1922—ALASKA OATS

YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	2483	2593	2468	2404	2237	12185
2	2503	2183	2140	1957	2260	11043
3	2485	2483	2452	2167	2366	11953
4	2425	2494	2213	2153	2254	11539
5	2697	2399	2435	2353	2356	12240
6	2747	2250	2597	2548	2465	12607
7	2731	2524	2786	2521	2544	13106
8	2391	1987	2535	2622	2589	12124
9	2266	2051	2147	2432	2686	11582
10	2342	2412	2461	2157	2268	11640
11	2155	2069	2587	2078	2324	11213
12	2144	2169	2572	2565	2263	11713
13	1773	2392	2803	2375	2200	11543
14	2000	2634	2453	2608	2580	12275
15	2378	2436	2762	2775	2384	12735
16	1878	2385	2453	2586	2413	11715
17	2318	2462	2761	2755	2283	12579
18	2306	2775	2957	2416	2388	12842
19	2225	2628	2795	2535	2402	12585
20	2208	2762	2602	2479	2320	12371
21	2243	2768	2559	2770	2604	12944
22	2329	2887	2832	2581	2417	13046
23	2490	2682	2837	2779	2451	13239
24	2681	2699	2681	2739	2778	13578
25	2298	2740	2667	2549	2245	12499
26	2590	2570	2822	2571	2415	12968
27	2333	2686	2424	2330	2348	12121
28	2253	2566	2120	2220	2434	11593
29	2264	2217	2273	1904	2053	10711
30	2043	2168	2037	1740	1749	9737
31	1739	1915	2171	1817	1322	8964
32	1118	1705	1776	1621	1322	7542
33	781	1377	1879	1639	1536	7212
34	871	1431	1604	1211	1044	6161
35	1075	1443	1508	1364	1093	6483

RANGE 3—1923—ALASKA OATS

YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	3660	3840	4250	4295	4250	20295
2	3645	3640	3775	4160	4375	19595
3	3825	3765	3615	3905	4280	19390
4	3360	3620	3660	3675	4305	18620
5	3165	3555	3590	3920	4075	18305
6	3615	3985	4120	3990	3865	19575
7	4180	4260	4175	4080	4175	20870
8	4100	3665	3960	4245	4275	20245
9	4050	3795	4195	4295	4165	20500
10	4085	4230	4040	4210	4110	20675
11	3760	4110	4255	4285	4235	20645
12	3465	3705	3840	4195	4160	19365
13	3610	3935	3930	4070	3930	19475
14	4010	3485	3670	3590	3515	18270
15	3425	3185	3035	3430	3275	16350
16	3430	3250	3145	3290	3275	16390
17	3150	3175	3005	3100	3065	15495
18	3145	3070	2790	3085	3175	15265
19	3290	3110	3055	3060	3340	15855
20	3220	3300	3180	3370	3405	16475
21	3950	3700	3825	3890	3875	19240
22	3530	3750	3715	4260	4345	19600
23	3170	3320	3180	3650	3875	17195
24	3515	3535	3300	3540	3940	17830
25	3855	3515	3605	3950	4275	19200
26	3950	3905	3575	3920	4280	19630
27	3420	3585	3745	4015	4330	19095
28	3270	3850	4075	4240	4630	20065
29	3740	4075	4135	4320	4300	20570
30	3940	3960	4040	4380	4550	20870
31	3780	4145	4040	4260	4425	20650
32	3985	3960	4100	3830	4280	20155
33	4320	3835	4030	4125	4010	20320
34	4030	3680	3850	3720	4065	19345
35	4215	3875	4140	3900	3605	19735

RANGE 3—1924—ALASKA OATS

YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	615	800	1050	1195	1125	4785
2	535	575	695	1355	1360	4520
3	510	745	1095	1600	1600	5550
4	685	910	1200	1955	1825	6575
5	590	800	795	1715	1485	5385
6	615	575	815	1345	1205	4555
7	800	505	1235	1680	1420	5640
8	625	735	1270	1010	945	4585
9	700	645	1060	1190	1125	4720
10	1000	1120	915	1305	1365	5705
11	680	885	1010	1615	1125	5315
12	715	770	1000	1445	1085	5015
13	815	950	885	1190	1060	4900
14	725	785	980	675	645	3810
15	650	685	750	815	695	3595
16	635	680	530	640	655	3140
17	535	610	475	495	380	2495
18	530	485	470	575	475	2535
19	585	515	560	525	550	2735
20	425	485	885	1060	885	3740
21	740	690	935	1400	1175	4940
22	740	1080	1025	1575	1310	5730
23	825	1230	975	1335	1210	5575
24	1060	1390	1110	1135	780	5475
25	1260	1430	1485	1625	1015	6815
26	990	1345	1435	1650	1100	6520
27	1430	1695	2015	1575	1435	8150
28	1275	1500	1630	1950	1530	7885
29	1855	2630	2055	2850	1995	11385
30	1775	2430	1630	2120	1945	9900
31	1605	1765	1575	1940	1715	8600
32	2260	2035	1955	2275	1585	10110
33	1360	1850	1665	1665	1530	8070
34	1575	1305	1385	1385	1700	7350
35	1400	1960	1415	1870	1715	8360

RANGE 3—1926—ALASKA OATS

YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	2974	3979	4219	4327	3729	19228
2	3180	4382	4113	4579	4571	20825
3	3029	4044	4228	4293	5061	20655
4	2643	4315	4101	4466	4835	20360
5	2678	4000	3785	4185	4148	18796
6	2500	4424	4850	4837	4566	21177
7	3891	4497	4766	5374	4616	23144
8	4200	4825	4355	4919	5114	23413
9	4880	5337	5163	5210	5221	25811
10	3968	5146	4507	4584	4510	22715
11	3390	4911	4197	4600	4000	21098
12	3175	4451	4145	4087	3369	19227
13	3400	4252	3888	3603	3985	19128
14	3414	4500	4163	4325	3897	20299
15	3243	4035	3850	3778	4002	18908
16	2925	3995	4017	3928	3600	18465
17	2782	3714	3835	3822	3148	17301
18	2940	3760	3586	3777	3033	17096
19	3096	3997	3997	3954	3194	18238
20	3513	4095	4121	4187	4028	19944
21	3908	3834	4057	4627	4175	20601
22	3874	4203	4330	5140	4500	22047
23	3832	4170	4015	4675	4100	20792
24	4120	3834	4399	4781	4077	21211
25	3937	4167	4821	4656	4070	21651
26	3921	4117	4119	4296	4296	20749
27	3879	4349	4579	5261	5100	23168
28	3909	4238	4841	5700	5048	23736
29	4213	5087	4498	5060	5213	24071
30	4463	5534	4956	5104	5352	25409
31	5084	5087	4756	5171	4940	25038
32	5385	5427	4873	5414	4843	25942
33	5553	5614	4902	5046	5208	26323
34	5532	5324	5228	4838	5361	26283
35	5358	5373	4974	5289	5205	26199

RANGE 3—PLOTS 20 x 100 LINKS (WEIGHT IN POUNDS)

Plot No.	North Western Dent 1927	Oats Alaska 1928	First Year Hay 1929	Second Year Hay 1930	North Western Dent 1931	Oats Cartier 1932
1	57.48	26.5	131.66	100.10	92.0	41.0
2	64.39	25.5	128.27	97.76	94.3	39.0
3	65.44	28.6	125.31	101.09	93.9	38.5
4	61.59	31.5	126.85	96.12	94.2	38.0
5	65.31	31.8	130.24	95.15	91.2	38.0
6	70.51	36.8	121.85	94.38	91.0	44.0
7	70.02	30.0	129.72	94.67	94.0	46.0
8	68.19	29.5	132.57	96.42	100.6	46.0
9	68.92	32.6	131.07	102.41	104.4	47.5
10	69.50	32.0	134.10	97.60	97.1	47.0
11	62.22	30.3	136.95	92.66	102.2	45.0
12	65.22	28.5	131.77	89.35	95.9	40.0
13	61.27	25.5	133.02	92.96	102.2	40.0
14	63.13	29.3	132.00	94.01	96.9	42.0
15	61.70	28.5	130.21	96.43	99.1	40.5
16	60.03	27.5	133.82	103.40	98.3	39.0
17	60.25	29.5	122.90	106.38	100.6	41.5
18	59.34	29.7	120.66	103.31	99.9	39.0
19	57.80	31.5	120.97	103.86	102.4	41.5
20	63.28	30.0	107.38	103.37	96.8	41.0
21	61.98	27.5	110.94	103.07	90.7	39.5
22	63.48	27.6	101.96	102.00	95.8	43.5
23	65.91	26.2	95.31	97.42	95.6	36.0
24	63.33	26.7	101.31	103.93	91.8	36.0
25	66.85	26.5	119.38	102.95	86.8	38.0
26	66.00	26.0	121.20	97.60	88.8	38.0
27	62.83	27.5	126.79	97.77	86.2	43.0
28	64.88	28.7	130.48	99.66	92.7	42.5
29	66.10	29.5	138.82	98.64	106.8	48.0
30	68.03	33.5	136.56	102.07	104.9	48.0
31	65.67	29.5	138.38	99.99	106.2	48.0
32	66.05	29.8	132.52	104.04	103.3	50.0
33	65.95	32.0	138.62	106.09	107.8	50.0
34	67.99	30.5	138.14	103.25	102.8	49.0
35	69.82	32.0	141.40	101.48	108.2	48.5

RANGE 4—1924—ALFALFA (TOTAL OF 3 CUTTINGS)

YIELD OF DRY MATTER IN POUNDS PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	42.5	44.0	43.5	43.5	43.0	216.5
2	38.5	39.0	41.0	42.5	40.5	201.5
3	37.5	40.0	39.5	38.5	40.5	196.0
4	38.0	38.0	39.0	36.5	43.0	194.5
5	34.5	35.5	34.5	37.5	41.5	183.5
6	39.5	37.5	37.0	39.0	42.5	195.5
7	39.5	33.5	35.0	37.5	39.5	185.0
8	40.5	36.5	36.0	37.5	39.0	189.5
9	39.5	38.0	36.5	38.5	39.5	192.0
10	40.5	38.5	37.5	39.0	44.0	199.5
11	42.5	43.0	41.5	42.0	47.5	216.5
12	49.5	46.0	46.0	46.5	51.5	239.5
13	50.0	44.5	44.0	44.5	46.0	229.0
14	46.5	44.5	45.0	45.0	46.0	227.0
15	45.5	43.5	43.5	46.0	46.5	225.0
16	47.5	44.5	46.0	44.5	48.0	230.5
17	51.0	48.0	42.0	43.0	47.0	231.0
18	51.5	48.0	44.0	44.0	47.0	234.5
19	50.0	45.0	42.5	41.5	44.0	223.0
20	49.5	45.0	44.0	42.0	46.5	227.0
21	48.5	47.5	45.0	46.5	48.5	236.0
22	44.0	45.5	44.0	43.0	44.0	220.5
23	44.5	44.0	44.5	44.5	47.5	225.0
24	48.5	47.0	46.0	48.0	51.5	241.0
25	49.0	45.0	46.0	44.0	47.5	231.5
26	50.5	45.5	42.5	42.5	48.0	229.0
27	46.5	44.0	43.0	46.0	51.0	230.5
28	44.0	45.0	46.5	44.5	50.0	230.0
29	44.5	47.5	45.5	45.0	48.0	230.5
30	49.0	50.5	48.0	45.5	51.0	244.0
31	46.5	40.5	39.5	41.5	48.0	216.0
32	48.0	39.5	31.0	42.0	51.0	211.5
33	51.0	42.0	35.5	37.0	40.0	205.5
34	52.0	44.5	37.0	37.5	41.0	212.0
35	55.0	47.0	45.5	44.0	46.5	238.0

RANGE 4—1925—ALFALFA (TOTAL OF 2 CUTTINGS)
YIELD OF DRY MATTER IN POUNDS PER PLOT

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	30.87	27.56	29.50	27.87	26.06	141.86
2	28.75	31.44	34.69	30.25	29.62	154.75
3	32.44	32.00	31.75	28.62	31.75	156.56
4	29.50	28.50	28.25	28.50	31.37	146.12
5	28.50	30.81	28.00	29.25	33.50	150.06
6	30.75	30.81	31.25	32.00	33.31	158.12
7	31.50	29.75	28.75	30.93	33.75	154.68
8	33.06	31.12	31.00	31.44	32.62	159.24
9	32.12	30.81	30.00	32.31	32.75	157.99
10	32.50	32.12	31.00	32.19	35.37	163.18
11	35.00	31.81	32.50	32.62	35.25	167.18
12	35.25	35.31	31.75	34.44	35.56	172.31
13	34.75	33.50	31.25	33.50	33.25	166.25
14	35.00	33.50	33.00	38.00	34.25	173.75
15	34.50	33.00	33.75	34.00	34.75	170.00
16	34.75	35.75	33.00	35.00	34.50	173.00
17	38.75	34.25	36.50	33.75	34.25	177.50
18	38.00	39.25	35.75	33.50	33.50	180.00
19	38.75	36.00	33.75	30.00	33.75	172.25
20	38.50	34.50	30.75	30.50	29.50	163.75
21	38.00	34.75	33.00	33.00	33.75	172.50
22	40.00	39.75	36.00	37.25	35.00	188.00
23	39.75	38.25	36.25	36.25	40.50	191.00
24	38.25	40.00	36.25	38.00	41.75	194.25
25	37.75	38.50	38.25	36.75	41.75	193.00
26	39.50	40.50	38.75	39.75	39.50	198.00
27	38.50	39.25	38.75	36.75	37.50	190.75
28	35.25	38.25	34.25	36.75	37.25	181.75
29	38.50	39.00	36.75	38.00	40.25	192.50
30	41.50	36.25	39.00	36.50	38.50	191.75
31	41.50	38.30	36.25	37.25	42.00	195.30
32	42.75	35.25	32.25	37.75	40.75	188.75
33	42.50	36.75	34.50	34.25	39.75	187.75
34	41.75	37.75	34.25	36.25	41.50	191.50
35	43.75	38.75	37.25	39.00	40.75	199.50

RANGE 4—1926—MANGELS

YIELDS OF DRY MATTER IN POUNDS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	32.46	29.08	28.29	32.43	34.09	156.35
2	36.77	34.07	32.51	32.76	32.40	168.51
3	32.97	29.08	30.29	32.26	34.32	158.92
4	32.95	32.76	30.86	33.55	31.52	161.64
5	32.90	32.28	30.80	31.84	34.61	162.43
6	35.53	33.17	31.11	34.33	35.03	169.17
7	32.09	33.79	31.96	35.64	34.57	168.05
8	35.31	34.71	33.00	31.34	32.34	166.70
9	34.21	32.58	31.87	35.21	33.44	167.31
10	32.38	33.25	33.53	33.26	33.43	165.85
11	34.82	35.53	31.52	34.50	32.84	169.21
12	33.16	33.78	33.33	35.03	36.99	172.29
13	33.03	35.60	36.54	36.10	37.63	178.90
14	36.69	39.45	33.00	36.71	34.48	180.33
15	36.17	34.54	34.37	36.30	34.99	176.37
16	31.43	33.58	33.47	33.03	34.54	166.05
17	33.55	34.63	31.79	35.02	38.49	173.48
18	30.64	34.19	33.19	36.22	37.00	171.24
19	37.98	36.97	34.02	34.19	36.99	180.15
20	34.32	35.74	31.63	35.34	34.74	171.77
21	32.35	32.94	31.43	32.88	35.75	165.35
22	36.41	33.87	31.17	36.06	35.72	173.23
23	32.66	32.52	30.87	33.64	35.99	165.68
24	34.80	37.40	32.61	33.36	34.99	173.16
25	36.09	34.83	31.32	36.49	34.16	172.89
26	36.89	36.42	34.36	34.72	35.01	177.40
27	36.51	34.95	34.56	34.18	33.38	173.58
28	36.34	35.93	33.63	35.16	32.34	173.40
29	34.44	38.69	34.32	33.00	34.78	175.23
30	37.50	37.18	34.05	34.51	34.60	177.84
31	34.22	33.69	33.50	35.84	34.01	171.26
32	38.72	39.22	34.57	34.25	33.09	179.85
33	37.63	35.90	33.39	32.63	34.95	174.50
34	35.62	34.11	33.46	34.90	32.62	170.71
35	39.63	35.47	33.49	33.86	40.62	183.07

RANGE 4—PLOTS 20 x 100 LINKS (WEIGHT IN POUNDS)

Plot No.	North Western Dent 1928	Oats Alaska 1929	First Year Hay 1930	North Western Dent 1932
1	79.45	29.0	154.38	78.53
2	79.16	28.5	142.77	80.67
3	76.16	30.0	141.73	75.51
4	79.22	29.0	142.29	75.05
5	80.96	28.5	138.76	73.84
6	77.69	29.0	139.39	77.50
7	82.01	30.0	148.21	80.94
8	80.67	27.5	146.38	81.79
9	78.65	28.0	150.52	81.44
10	77.94	29.0	151.36	79.74
11	78.93	28.2	146.33	76.22
12	82.42	29.5	152.27	81.46
13	85.18	32.5	157.60	82.25
14	83.06	32.7	158.27	81.16
15	83.34	34.0	161.87	80.37
16	84.93	30.5	158.03	78.21
17	80.62	29.2	159.32	74.84
18	85.57	30.0	157.90	75.54
19	79.05	31.0	162.64	78.82
20	83.02	31.0	160.43	86.05
21	82.48	29.3	161.91	83.54
22	81.22	29.2	160.31	87.86
23	83.55	33.6	154.67	83.91
24	80.91	34.0	156.59	85.00
25	82.24	32.5	159.39	84.49
26	86.85	37.0	162.51	87.56
27	82.03	37.2	161.47	92.51
28	85.02	36.5	163.93	91.96
29	84.81	37.5	170.26	88.60
30	82.64	36.5	167.58	91.66
31	80.37	37.5	168.86	87.60
32	79.77	35.0	167.55	87.10
33	82.19	34.6	166.44	88.67
34	84.60	34.5	161.67	90.05
35	84.72	31.5	162.45	89.31

RANGE 5—1924—BANNER 44 OATS

YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	2400	2620	2750	2700	2250	12720
2	2960	2825	2590	3075	3000	14450
3	3000	2905	2735	3280	2640	14560
4	3050	2515	2965	3325	2900	14755
5	3025	3105	3170	3350	2865	15515
6	3240	3445	2975	3315	2810	15785
7	3190	3515	3250	3565	2555	16075
8	3155	3425	2920	3240	2595	15335
9	3320	3490	2800	2850	2535	14995
10	2770	3000	2865	3025	2375	14035
11	3165	3530	3150	3105	2510	15460
12	2960	3350	3090	3200	2570	15170
13	3020	3710	2900	2775	3160	15565
14	3160	3585	2990	2840	2615	15190
15	3270	3650	3490	2610	2895	15915
16	3050	3905	3470	3410	2825	16660
17	3000	3415	3555	2950	3095	16015
18	2865	2890	2595	2790	2580	13720
19	3575	3195	2860	2660	2995	15285
20	3205	3310	2665	3280	2725	15185
21	3595	3465	2885	3490	3050	16485
22	3580	3700	3175	3180	2750	16385
23	3740	3605	3355	3200	2620	16520
24	3775	3655	3515	3565	2975	17485
25	4000	3830	3605	3325	3100	17860

RANGE 5—1925—BANNER 44 OATS
YIELD OF GRAIN IN GRAMS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	1925	2240	2730	2781	2180	11856
2	2790	2860	2856	2760	3060	14326
3	2610	3305	2950	2940	3255	15060
4	3210	3530	3340	3425	3065	16570
5	2970	3390	3455	3490	3000	16305
6	2555	3130	3315	3690	3160	15850
7	2505	3105	3180	3435	3055	15280
8	2500	2848	2705	2960	2735	13748
9	2445	3250	3010	3160	2825	14690
10	2450	3305	2940	3038	2648	14381
11	2990	3428	3357	3960	3670	17405
12	3330	3900	3940	4170	3655	18995
13	3705	4520	4380	3860	3390	19855
14	4430	4980	4220	3680	3915	21225
15	4150	4400	3865	4125	3785	20325
16	3440	3955	3945	4220	4095	19655
17	3455	4038	3675	3480	3435	18083
18	3640	3990	3550	3502	2855	17537
19	3210	3450	3975	3760	3135	17530
20	3350	3670	3710	3645	2900	17275
21	3415	3450	3485	4085	3515	17950
22	3075	3455	4120	4100	3360	18110
23	3150	3500	3830	4130	3130	17740
24	3120	4030	3665	3775	3650	18240
25	3080	4000	3770	3875	3300	18025

RANGE 5—1926—BANNER 44 OATS

YIELD OF GRAIN IN GRAMS PER PLOT.

Plot No.	Plots 20 x 20 Links					Plots 20 x 100 Links
	Series 1	Series 2	Series 3	Series 4	Series 5	
1	4550	4295	4190	4230	4650	21915
2	4510	4583	4120	4336	4664	22213
3	4120	5030	4288	4342	4795	22575
4	4475	4577	4060	4370	4630	22112
5	4481	4984	4411	4420	4770	23066
6	4425	4604	4061	4385	4752	22227
7	4340	4422	3880	4295	4965	21902
8	4100	4580	4002	4176	4645	21503
9	4578	4433	4006	4491	5202	22710
10	4748	4585	4275	4565	4940	23113
11	4500	4744	4413	4639	5121	23417
12	4775	4857	4745	4380	4880	23637
13	5010	4300	4670	3800	4295	22075
14	4981	4255	4634	3825	4123	21818
15	4675	4526	4188	4382	4500	22271
16	5186	4682	4178	3550	5309	22905
17	4515	4072	3870	4229	4275	20961
18	4575	3642	3560	3860	4364	20001
19	4276	3965	3865	4005	4330	20441
20	4798	3780	4370	4020	4858	21826
21	4152	4034	4082	4384	4972	21624
22	4170	4311	4469	4620	4990	22560
23	3710	4054	4188	4722	5100	21774
24	4865	4730	4368	4480	4890	23333
25	4725	4295	4266	4345	4270	21901

RANGE 5—1927—MANGELS

YIELD OF DRY MATTER IN POUNDS PER PLOT

Plot No.	Plots 20 x 20 Links Series 1	Series 2	Series 3	Series 4	Series 5	Plots 20 x 100 Links
1	24.19	26.16	22.97	24.16	22.57	120.05
2	25.71	24.18	22.57	23.39	24.85	120.70
3	23.45	12.60	22.13	25.32	23.57	107.07
4	25.59	12.95	23.30	22.64	22.91	107.39
5	24.11	26.99	23.01	22.99	23.41	120.51
6	23.61	24.44	20.37	23.46	23.20	115.08
7	22.18	24.06	22.96	23.66	22.76	115.62
8	18.90	22.71	20.13	22.37	26.32	110.43
9	22.01	22.67	22.13	24.64	24.61	116.06
10	21.94	26.99	23.27	27.12	24.69	124.01
11	25.75	29.39	25.40	27.53	27.88	135.95
12	24.68	28.77	23.43	27.51	27.60	131.99
13	26.75	27.35	27.09	29.03	27.98	138.20
14	26.72	28.28	27.20	29.65	26.85	138.70
15	29.11	28.88	26.30	28.89	26.89	140.07
16	27.09	29.10	24.79	27.79	27.73	136.50
17	26.27	27.86	25.91	25.54	25.55	131.13
18	30.76	30.40	23.76	26.76	23.81	135.49
19	26.72	27.41	23.35	24.66	25.15	127.29
20	24.93	23.84	21.60	23.89	24.75	119.01
21	25.36	27.42	23.28	23.21	25.01	124.28
22	25.79	25.65	25.84	28.53	26.24	132.05
23	24.28	25.00	25.19	28.61	16.43	119.51
24	26.48	28.39	24.91	29.92	27.95	137.65
25	24.22	28.63	26.86	28.59	27.95	136.25

RANGE 5—PLOTS 20 x 100 LINKS (WEIGHT IN POUNDS)

Plot No.	Oats Alaska 1928	North Western Dent 1929	Oats Alaska 1930	First Year Hay 1931	Timothy 1932
1	37.0	48.64	42.0	110.8	54.21
2	36.5	58.44	43.5	113.0	61.18
3	35.0	58.56	45.5	117.3	62.33
4	36.3	61.23	43.5	115.5	64.65
5	35.4	59.18	42.0	111.0	65.91
6	35.3	59.42	41.0	112.1	64.89
7	31.0	55.59	39.0	108.8	66.54
8	31.0	52.11	40.0	111.4	67.66
9	33.9	56.29	41.0	112.6	69.37
10	37.2	58.43	44.0	111.7	71.93
11	38.0	65.21	45.5	118.4	84.68
12	37.5	66.75	47.5	122.4	87.95
13	39.1	64.09	47.0	127.8	92.13
14	40.5	61.30	47.0	126.7	93.18
15	39.3	60.09	47.0	125.6	90.46
16	38.0	62.74	47.5	121.0	84.89
17	34.3	55.22	43.0	116.5	79.69
18	33.0	53.98	42.0	117.7	69.83
19	34.5	51.98	45.0	115.8	79.37
20	33.4	56.25	43.5	105.0	77.60
21	34.5	60.80	40.5	112.2	78.41
22	36.0	57.95	42.5	111.4	77.01
23	35.0	66.25	44.0	120.9	80.18
24	33.5	66.08	45.0	121.0	86.48
25	36.8	67.63	46.0	118.6	84.20